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COLLEGE OF BASIC AND APPLIED SCIENCES

PERFORMANCE CHARACTERISTICS OF A SUITABLE FABRIC FOR GHANAIAN PUBLIC BASIC SCHOOL UNIFORMS

BY

PATIENCE ASIEDUAH DANQUAH

(ID NO: 10498728)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF PHD FAMILY AND CONSUMER SCIENCES DEGREE.

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DECLARATION

I, Patience Asieduah Danquah, do hereby declare that this thesis was produced from research carried out as a PhD candidate in the Department of Family and Consumer Sciences, University of Ghana, Legon. This work is an original research and that neither the whole nor part of it has been presented for another degree in this university or elsewhere.

..... Date.....

Patience Asieduah Danquah

(PhD Candidate)

Supervisory Team:

..... Date.....

Professor Docea Fianu

..... Date.....

Dr. Efua Vandyck

..... Date.....

Dr. Cynthia Gadegbeku

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ABSTRACT

Experimental procedures were employed to evaluate three fabric brands (A, B and C) currently used for Ghanaian-Public-Basic-School Uniforms and to select one that met standard specifications by the Ghana Standards Authority (GSA) for school uniforms. The study was in two phases. Phase one evaluated the fabric brands by using standards test methods recommended by GSA from the International Organisation of Standardisation (ISO) for breaking strength, fibre and weave types, weight, colourfastness and shrinkage to washing characteristics. Based on the Phase one results, fabric B was selected and used for Phase two which involved seam performance evaluation. A 2×3×3 factorial experiment (two brands of sewing threads, three ranges of stitch densities and three cycles of washing) was used to assess the strength, elongation and efficiency of plain seam in the selected fabric. The total number of specimens used for Phase one was 366 and for Phase two, 240. The instruments employed for the investigations were the Standard Launder-Ometer (Gyrowash 315) for washing of specimens, tensile testing machine (Mark-10 Force Gauge Model M5-500) for testing breaking strength and elongation of specimens, sample cutter (James H. Heal, 230/002595) for cutting specimens for weight and weighing balance (Adams equipment, B215846278) for weighing the specimens. The data for the study was analysed by the use of the Predictive Analytic Software (SPSS). Means and standard deviations of the fabrics performance characteristics such as yarn count, weight, strength, elongation and yarn linear density were calculated. Inferential statistics (Analysis of Variance and Independent samples *t*-test at 0.05 alpha levels) were employed in testing the hypotheses. The findings revealed that all the uniform fabrics studied contained varied proportions of cotton and polyester fibres

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except one that was a blend of polyester and viscose rayon. Fabrics B and C were blends of cotton and polyester (21% cotton/79% polyester; 1% cotton/99% polyester respectively) while fabric A was 35% Viscose/65% polyester. In all the parameters evaluated fabric brand B met the standard specifications for strength (warp= 401, weft= 372), weight (138g/m^2), shrinkage (2% for both warp and weft), and colourfastness (5).Significant differences were found among the strengths, weights, elongations and yarn counts of the investigated fabrics. The different brands of sewing threads (A′ and B′) were 100% polyester with brand B′ performing better in terms of seam strength (warp=206N, weft=262N), elongation (warp=40%, weft=26%) and efficiency (warp=60%, weft=61%). Those of A′ were warp 179N and weft 193N for strength, elongation 36% and 20% for warp and weft respectively and efficiency 51% and 45% for warp and weft respectively. With regard to the stitch densities, 14 stitches per 2.5cm (1 inch) performed best in terms of seam strength (warp=225N, weft=276N), elongation (warp=45%, weft=29%) and efficiency (warp=63%, weft=65%). The findings have established the suitability of a fabric used to produce Ghanaian-public-basic-school uniforms and showed that to achieve good quality school uniforms, appropriate selection of fabrics and sewing parameters are important. It is recommended that a copy of the thesis is given to stakeholders in the garment industry in Ghana to organise outreach programmes, seminars, workshops and conferences to educate garment makers on the need to select suitable fabrics, sewing threads and stitch densities for good quality school uniforms production.

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DEDICATION

I dedicate this thesis to my lovely children, Nana Adom, Nhyiraba and Efua Aseda Monnie.

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LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
ISO	International Organisation for Standardization
GSA	Ghana Standards Authority
AATCC	American Association of Textile Chemist and Colorist
ANSI	American National Standards Institution (ANSI),
BSI	British Standards Institute
SPI	Stitches Per Inch

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Clothing is a silent language that has a silent vocabulary which takes the form of symbols (signs, cues, icons) used by individuals and groups as tools for social interaction (Marshall, Jackson & Stanley, 2012). For instance, government institutions, religious organisations, informal groups and schools use particular types of clothes which easily identify them and such clothes are termed uniforms. Uniforms are a particular set of clothes worn by members of the same organisation or group of people (Cambridge Advanced Learner's and Thesaurus Dictionary, 2016). The use of uniforms is worldwide and in Africa, uniforms are widely accepted (Kadiadze, 2014). In Ghana, the wearing of school uniforms is an important social aspect of the school system. In both urban and rural schools throughout the country, be it government, mission or private schools, the school pupils wear uniforms.

Uniforms perform several functions (Kantheti, Devi & Anitha, 2015). In the view of Kantheti et al. (2015), many believe that uniforms are a reflection of a school's disciplinary standards. Several authors on school uniforms believe that they play a very important role in societies and bring a lot of advantages to the educational system. For instance, Nkiwane (1992) indicated that a school uniform provides a physical feeling of equality among all pupils. This is because when in uniform, poorer pupils do not feel ashamed of what they are wearing as they are clothed like anyone else. Good quality uniforms are therefore required by school pupils and students to carry out their activities properly. Nkiwane (1992) noted that clothing should not only

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provide a covering for the skin, but should be well designed, pleasing to look at, comfortable to wear and durable. Kantheti et al. (2015) also stated that clothing should be able to fulfil the requirements of the wearer while working in different conditions and situations. For instance, for children, their clothing should be able to withstand their continuous body movements. Children therefore require a school uniform which is comfortable, functional without hindering talents and activities and of good quality (Kantheti et al., 2015). Senthilkumar and Dasaradan (2007) mentioned that clothing comfort comes in three dimensions. These are physical (ability of the garment to absorb sweat and keep the body cold or warm as required for the activity in which the individual is involved), psychological (ability of the garment to provide the individual a feeling of wellbeing, sense of belonging and boost his or her confidence) and social (ability of the garment to make an individual wearing it to feel socially acceptable). If clothing is uncomfortable for children, it may interfere with their ability to concentrate in the classroom (Kantheti et al., 2015). From personal experience some pupils and students may even drop out of school due to denigrating comments from friends. For example, a pupil in a tattered and faded uniform will feel uncomfortable; indicating the need for good quality school uniforms for pupils and students for their satisfaction in carrying out all the activities required.

Quality, according to Mehta and Bhardwaj (1998), is defined by the International Organisation for Standardization (ISO) as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. This means quality is a product's ability to fit its use or its fitness for use. Quality is one attribute that most consumers look out for in a textile and an apparel product; though it varies from individual to individual (Chuter, 2002; Mehta & Bhardwaj, 1998).

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Consumers always want to benefit from the money they spend on goods and services. Chowdhary and Poynor (2006) and Pavlinic and Geršak (2009) indicated that garment quality is influenced by the right choice of textile materials (e. g. fabric) and garment construction parameters (e.g. stitches and seams). Masteikaitė, Sacevičienė, Apparova, and Gerasimovic (2013) reported that to produce good quality uniforms, it is very important to select suitable fabrics and construction procedures that will allow children to move easily without restricting their activities. Doshi (2006) and Keiser and Garner (2012) added that there is a direct correlation between fabric quality and garment quality.

1.2 Importance of Fabric and Seams in Determining Garment Quality

1.2.1 Fabric as a Determinant of Garment Quality

Fabrics are the basic raw material for the manufacture of garments and good quality fabrics are important for garments to function properly to meet their required end-uses (Behera, 2015). Behera (2015) further indicated that specifications for different end-use requirements vary. However, the selection of an appropriate fabric for a particular end-use is one of the most difficult tasks for the clothing manufacturer (Behera, 2015). This may be due to the increase in the variety of fabrics on the market caused by the development of new fibres and enhancement of new fabric structures (Tang & Stylios, 2006). According to Luible, Varheemaa, Magnenant-Thalmann and Meinander (2007), fabrics for different activities, climates and trends are developed and available on the market to guarantee an optimal quality of garments for consumers. Luible et al. (2007) noted that each textile fabric has particular properties which are beneficial for some types of garments but can be unfavourable for others

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depending on their end-use requirements. For example, requirements for fire-fighter garment are different from that of a school uniform.

Garments produced from high-quality fabrics for particular end-uses perform satisfactorily during use (Behera & Hari, 2009; Behera, 1999). However, various researches conducted on uniforms have indicated poor performance issues which are related to the fabrics used for their production. Kantheti et al. (2015) for instance, in their study on the features preferred in school uniforms by primary school children in Hyderabad (a city in India) found that the children preferred cotton patterned fabric which could absorb sweat while engaged in physical activities. Kantheti et al. (2015) further noted that their school uniforms were durable from one year to two years with the majority of the respondents (88 out of 100) indicating one year. In addition, most mothers indicated that the uniforms faded easily and the parts of the uniform that wore out easily were collars and sleeves. Poor quality fabrics used for the uniform production was indicated as the factor contributing to the poor durability of uniforms (Kantheti et al., 2015). Kadiadze, in 2014, studied selected Senior High Schools in the Cape Coast Metropolis of Ghana to determine their satisfaction with their school uniforms and found that the students discarded their uniforms early in use due to the poor colour fastness of the fabric.

The poor quality of uniforms experienced might be due to the selection of fabrics of inferior quality not suitable to be used for the production of uniforms. As indicated by Tang and Stylios (2006) the use of an unsuitable or inferior quality fabric for a particular end-use such as school uniform garments fundamentally determines the success or failure of a textile product. Thus, it is very important to assess the quality

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of a textile fabric before the production of a garment for a particular end-use (Luible et al., 2007). The assessment of the fabric includes subjecting the fabric to conditions it will encounter during use and care as garment to establish fabric suitability.

The quality and performance characteristics of fabrics for different end-uses include; strength, elongation, weight, thickness, dimensional stability, colourfastness, fabric weave, fibre content, yarn count, abrasion resistance, pilling resistance, drape, wrinkle and crease recovery and bending properties (Behera, 2015; Chan et al., 2006; Glock & Kunz, 2005; Kadolp, 2007; Masteikaitė et al., 2013; Mehta & Bhardwaj, 1998; Pizzuto, 2012). For uniform fabrics, Masteikaitė et al. (2013) and Ünal, Yildiz & Özdil (2011) identified essential properties such as high tensile strength, tear strength, dimensional stability, abrasion resistance, weight, good fastness to washing, breaking elongation and fibre content. The performance properties of fabrics are also influenced by factors such as the kind of raw material used, yarn twist, cover factor, type of dye and fabric construction method (Adetuyi, & Akinbola, 2009; Pizzuto, 2012; Teli, Khare & Chakrabarti, 2008).

1.2.2 Seam as a Determinant of Garment Quality

After a good quality fabric is selected, based on the end-use requirements, quality constructional procedures such as stitches and seams suitable for the selected fabric become another very important criterion to determine the overall quality of the finished garment. As indicated by Olsen (2008), one of the major reasons for the consumer being dissatisfied with a garment, after poor colour fastness and stability, is when the seams in a garment rip apart. The wearing property of a sewn garment is affected by the quality of its seams, which form the basic structural element of the

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garment (Bharani & Gowda, 2012). According to Nassif (2013) in Cut and Sew Apparel Products, seams are formed when two or more pieces of fabrics are held together by stitches. He further stated that as a seam is one of the basic requirements in the construction of apparel, seam quality has great significance in apparel products. LaPere (2006) and Mukhopadhyay, Chatterjee, and Ahuja (2014) pointed out that the seam of a fabric or garment is the most important parameter to maintain a product's quality. A poor quality seam makes a garment unusable even though the fabric may be in good condition. Mehta and Bhardwaj (1998) indicated that if a product bought has a deficiency, it cannot be used, and poor quality seams is a deficiency mostly encountered in the life of sewn garments.

The performance and quality parameters of seams include seam strength, elongation/elasticity, durability, slippage, puckering, efficiency, appearance and yarn severance (Bharani & Gowda, 2012; Carr & Latham, 1994; Cheng & Poon, 2002: Dobilaite & Juciene, 2006; Gurarda & Meric, 2007; Midha, Mukhopadhyay & Kaur, 2009; Mukhopadhyay et al., 2014). However, Mukhopadhyay et al., (2014) and American Society for Testing and Materials (ASTM) D6193 (2009) stated that priority given to any of the parameters may vary, depending on the end-use of the seamed product. For example, a school uniform will require high seam strength as it will go through frequent washing due to the activities of school children which include play. For a perfect fitting and look of a garment, Doshi (2006) stated that seam appearance and its strength have to be appropriate to enhance the quality of the garment to meet its required end use. Many previous studies (ASTM D6193, 2009; American & Efird Inc., 2009; Gurarda, 2008; Mukhopadhyay, Sikka & Karmaker, 2004) have pointed out that the seam quality parameters depend on the

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interrelationship among the type and weight of fabric, the type of needle, type and size of the thread, stitches per inch/2.5cm (SPI), type of seam selected. According to Choudhary and Goel (2013) fabric performance characteristics have influence on seam quality in garments. They indicated some of the fabric properties that influence seam quality as weight, thickness, strength and shrinkage. There is the need therefore to evaluate a fabric to determine its performance properties in order to select appropriate seaming factors such as threads and stitch densities that would aid in achieving quality in the final garment produced. Chowdary and Poynor (2006) reported that stitch density and stitch type, for example, influence the quality of seams in a garment and poor choice can make the best fabric and related materials perform poorly. Barbulov-Popov, Cirkovic and Steponavic (2012) in the study, on the influence of stitch density and type of sewing thread on seam strength found that seam strength depends on structural and construction parameters such as fibre and weave types of the fabric used, type of thread used as well as stitch density used in making the seam.

1.3 Importance of Evaluating Fabrics and Seams before Garment Production

As evident from the preceding paragraphs, it can be noted that to achieve quality in garments, fabrics and seams play major role, hence the need for their evaluation. When fabrics and their seams are not evaluated before garment production, poor quality garments that do not meet consumer expectations are likely to occur. Mothibi (2007) studied pupils and parents dissatisfaction with school uniforms in selected secondary schools in Botswana. Dissatisfaction with school uniforms was attributed to problems such as textile of inferior quality, poorly constructed garments, poor fit, colour fading and unfinished seams (Mothibi, 2007). It was also observed that the

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majority of the pupils did some repairs (such as seam repairs) to their uniforms within the first six months of use. Nkiwane (1992) also noted that the pupils he used in his study on the design and functions of school uniforms in Zimbabwe were not pleased with the uniforms functional values. The pupils complained of loosening buttons, small pockets and seams ripping apart (Nkiwane, 1992). Similarly, Koranteng (2015) found non-performance issues with uniforms produced in Ghana such as ripped seams and unfinished edges.

Various researches have been undertaken to identify a range of fabrics suitability to be used for different end uses. Such researches include: identifying fabrics to be used as uniforms for the military (Juodsnukyte, Gutauskas & Čepononiene, 2006; Kovacevic, Schwarz & Durasevic, 2012), airline, departmental store, retail, bank and government departments (Chan, et al., 2006) and schools (Adetuyi & Akinbola, 2009; Masteikaitė, et al., 2013; Özdil, Boz, Ünal & Mengüc, 2014; Ünal, et al., 2011). For example, according to Masteikaitė et al. (2013) children's physical activity must be evaluated at the stage of school uniforms design. They stated that comfort of school uniforms depends not only on their construction but also on the properties of used fabrics. Masteikaitė et al. (2013) therefore analysed performance properties (such as breaking strength, breaking elongation, weight and shear rigidity) of seven different fabrics to determine their suitability for school uniforms. Adetuyi and Akinbola (2009) also investigated performance properties such as colourfastness, tensile strength of school uniform fabrics for pre and post-primary schools in Akure metropolis, Nigeria to establish which ones were suitable for use.

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1.4 Observation of Public Basic School Uniforms in Ghana

Observation made of uniforms sold at the markets in Ghana, indicated variations in the types of fabrics used in producing the uniforms. There are also variations in the stitch densities employed by various garment makers. There is also the fact that there are wide varieties of threads on the market (Jonaitiene & Stanys, 2005). Danquah (2010) noted that some of the garment producers select stitch densities and sewing threads without paying attention to their effect on the overall performance of the apparel being made. These result in failure of the seam during use and care. Observation of pupils at the public basic school level showed that some pupils usually wear garments that are faded, worn out or torn and seams ripped apart. Some try to stitch them back and others leave them hanging or hold them with safety pins. Those that try to stitch them back in place are sometimes not able to achieve a very good outcome marring the appearance and the drape of the garment. Meanwhile, Mehta and Bhardwaj (1998) stated that quality apparel must perform satisfactorily in normal use, meaning that a garment must be able to withstand normal wearing and care without for instance, fabric fading and seams coming apart. However, the determination of best sewing parameters to be used for a particular assembly requires a thorough knowledge of many variables(e. g. thread type, stitch density, fabric type and seam type) ASTM D6193 (2009), which can only be established through testing (AMANN Inc., 2009). The improper selection of any one of the variables can result in failure of the product manufactured ASTM D6193 (2009).

1.5 Statement of the Problem

The performance and appearance of fabrics and seams form an important component of the quality and durability of a finished product such as a garment. Selecting high

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quality fabrics that meet the requirements for a particular end-use leads to the achievement of good quality garments. Factors such as fabric type being stitched, thread type and stitch density affect the quality of seams and contribute to the performance of a garment during use. Understanding the components of the fabric and the quality of the seam will ensure the best performance for that particular product. Observation and researches conducted on school uniforms indicate torn seams, worn out and faded garments on some pupils. These problems may be due to the selection of fabrics of poor quality not suitable for uniform manufacture as well as the choice of unsuitable threads and stitch densities for the uniform production. Although researches have been conducted on school uniforms, the performance of fabrics and seams of the fabrics used for Ghanaian public basic school uniforms have not received much attention. This study therefore, evaluated the performance of three common brands of fabrics currently used in the manufacture of public basic school uniforms in Ghana. Additionally, seam analysis was conducted by varying sewing thread brand, stitch density, and washing for a suitable fabric for uniform production. This was done to determine, among the sewing parameters identified, which ones would produce best results to help achieve overall quality in public basic school uniforms in Ghana.

1.6 Aim of the Study

The aim of this study was to;

Select a suitable fabric from the fabrics currently used for Ghanaian public basic school uniforms and evaluate seam performance characteristics of the selected fabric.

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1.7 Objectives of the Study

The specific objectives of the study were to;

1. Identify the fibre content of the fabrics used for the production of Ghanaian public basic school uniforms.
2. Establish differences among the number of times of washing and the performance characteristics (strength, elongation, weight and shrinkage) of the fabrics used for the production of Ghanaian public basic school uniforms.
3. Evaluate and select a fabric that meet the required standard specifications for uniform fabrics set by the Ghana Standards Authority (GSA).
4. Examine how two different brands of sewing threads would perform in terms of seam performance properties (strength, elongation and efficiency) of a suitable fabric for Ghanaian public basic schools uniforms.
5. Assess how three stitch densities would perform in terms of seam strength, elongation and efficiency of a suitable fabric for uniform production.
6. Establish differences among the number of times of washing and seam performance characteristics (strength, efficiency and elongation) for a suitable fabric for uniform production.

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1.8 Hypotheses

Ho_1: There is no significant difference among the:

a) Weights

b)Strengths

c) Elongations

d) Shrinkage and

e) Yarn counts of three different brands of fabrics used in the construction of Ghanaian public basic school uniforms.

Ho_2: There is no significant difference between the number of times of washing (wash cycles)and the:

a) Strengths

b) Elongations

c) Weights and

d) Shrinkage of the three different brands of fabrics used for Ghanaian public basic school uniforms.

Ho_3: There is no significant difference between:

a. Sewing thread brands used and the seam strength of a suitable fabric for Ghanaian public basic schools uniforms.
b. Stitch densities and the seam strength of a suitable fabric for Ghanaian public basic schools uniforms.
c. Wash cycles and the seam strength of a suitable fabric for Ghanaian public basic schools uniforms.

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Ho_4: There is no significant difference between:

a. Sewing thread brands used and the seam efficiency of a suitable fabric for Ghanaian public basic schools uniforms.
b. Stitch densities and the seam efficiency of a suitable fabric for Ghanaian public basic schools uniforms.
c. Wash cycles and the seam efficiency of a suitable fabric for Ghanaian public basic schools uniforms.

Ho_5: There is no significant difference between:

a. Sewing thread brands used and the seam elongation of a suitable fabric for Ghanaian public basic schools uniforms.
b. Stitch densities and the seam elongation of a suitable fabric for Ghanaian public basic schools uniforms.
c. Wash cycles and the seam elongation of a suitable fabric for Ghanaian public basic schools uniforms.

Ho_6: Sewing thread brands, stitch density and washing cycle have no significant influence on the seam:

a. Strength
b. Elongation and
c. Efficiency of a suitable fabric for Ghanaian public basic schools uniforms.

1.9 Significance of the Study

It was anticipated that the study would:

1. Highlight the brand(s) of fabrics on the market used for public basic school uniforms that meet standard requirements for uniform production.

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2. Recommend some sewing parameters such as brands of sewing threads and stitch densities that were likely to help achieve optimal quality in school uniforms.
3. Assist in understanding better the problem areas contributing to poor quality of uniforms experienced by parents and pupils and assist in shaping the approach to be adopted to attain good quality uniforms.
4. Provide objective statistical baseline data for effective communication and corporation among researchers, industry and traders of textile and clothing in Ghana; researchers can communicate to manufacturers the need to a) specify performance requirements for fabrics for various end-uses and b) manufacture fabrics that meet requirements for specific end-uses.
5. Act as a template for teaching and other researchers and the Ghana Standards Authority may use to investigate the performance of various fabrics on the Ghanaian market to determine whether they were fit for the purposes for which they are intended.
6. Add to the body of knowledge on the performance characteristics of fabrics and seams used for public basic school uniforms which can be used for teaching and research in the area of clothing and textiles.

1.10 Organisation of the Thesis

The thesis is divided into five chapters. Chapter one comprises the background to the study, statement of the problem, aim, research objectives, hypotheses and significance of the study. The second chapter reviews literature that supports the study. The chapter reviews literature related to the concept of clothing quality and provides the framework that guided the research. Furthermore, literature concerning school

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uniforms, quality in the garment industry, factors used to assess quality and how quality is evaluated in the textile and apparel industry are discussed. Chapter three discusses the methods used for the study, which include the research design, materials, instruments, sample and sample preparation, data collection procedures and the data analysis plan. Chapter four presents the findings and the discussion of the results of the study. Lastly, chapter five presents the summary of the study, conclusions and recommendations based on the findings.

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CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

The main objective of this chapter is to review some related literature to the topic. The significance of the review is to survey the pool of knowledge on the subject matter under study, work done by others on similar studies, and more importantly to create a context for analysing the data. The chapter is divided into three main sections with sub-sections. Section one, discusses the conceptual base and framework of the study. Section two, provides the history and importance of school uniforms and looks at quality issues related to uniform and garment production in Ghana. Section three presents information on quality in the textile and apparel industry, focussing on inspection and testing as a means of evaluating quality. Literature concerning standards and specifications and the performance characteristics of fabrics and seams are discussed.

SECTION ONE

2.2 Conceptual Base of the Study

The conceptual framework for this research is developed based on the concept of clothing quality. The concept is important as it provides the dimensions of apparel product quality that serve as a guide for determining quality of apparel products (Ratief & de Klerk, 2003). The diagrammatic representation of the concept of apparel product quality is shown in Figure 2.1, page 17.

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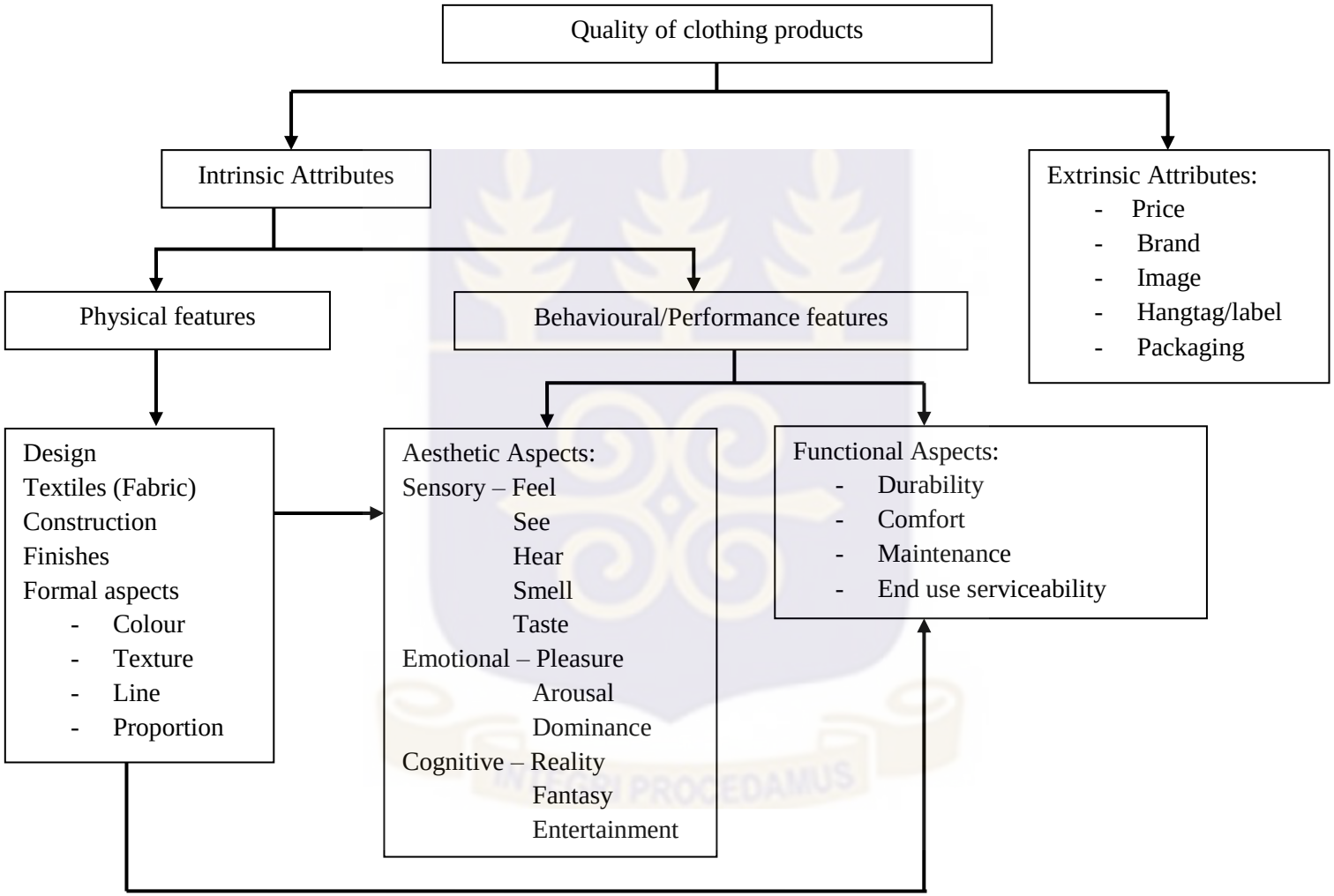


Figure 2.1: Concept of apparel product quality (Klerk & Lubbe, 2004; Retief & de Klerk, 2003)

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This section describes the concept of clothing quality bringing out the dimensions of quality that the concept provides and indicates its relatedness to the current study. Quality is defined by Chuter (2002) as the totality of features or characteristics of a product or service that contribute to its ability to satisfy a given need. Fowler and Clodfelter (2001) indicated that quality is regarded as one of the main reasons for a consumer's dissatisfaction with clothing products. However, quality attributes vary from individual to individual as indicated by Mehta and Bhardwaj (1998). The response of what quality is depends on people's perception of the value of a product or service under consideration and their expectations of performance, durability and reliability of that product or service. Generally, researchers have identified two evaluative cues for apparel products. They are intrinsic and extrinsic with each having specific attributes. As indicated by Zeithaml (1998), Schiffman and Kanak (2000), Chowdhary and Poynor (2006) and Glock and Kunz (2005) perceived apparel product quality is a function of intrinsic and extrinsic cues (see Figure 2.1, page 17).

Extrinsic cues to quality and performance are the textile product characteristics that are not component parts of the fashion product, but are allocated by the manufacturer or retailer (Hugo & Aardt, 2014). They include price, brand names, apparel firm's reputation, promotional strategies, product presentation, labels, country of origin and retailer's reputation (Chowdhary & Poynor, 2006; Glock & Kunz, 2005; Hugo & Aardt, 2014). Intrinsic cues are inherent part of the apparel product that cannot be altered without changing the product itself (Chowdhary & Poynor, 2006; Glock & Kunz, 2005). Brown and Rice (1998) provided features that fall under intrinsic quality cues that can be used as attributes in evaluating apparel quality. They grouped the features into two namely physical and behavioural (also known as performance). The

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physical dimension specifies what the clothing item is and the behavioural dimension indicates what the clothing item can achieve.

According to Brown and Rice (1998), the physical dimension of a garment describes the garment's tangible form and composition. The physical features include the fabric, the design of the garment, the construction (stitches and seams) and finishes applied (Ratief & de Klerk, 2003). According to Retief and de Klerk (2003), the behavioural or performance features also form part of the intrinsic attributes and determine what standards the product can meet. Sieben (1991), Brown and Rice (1998) and Geršak (2002) reported that the behavioural characteristics of clothing products is divided into aesthetic and functional behavioural characteristics (Figure 2.1). Aesthetic behavioural characteristics refer to the aesthetic experience of the clothing item whether on a sensory level, emotional or cognitive, for instance, does the garment meet current fashion trend?.

Functional behavioural characteristics on the other hand, refer to the durability and utility of the clothing product, such as the product's suitability for various purposes and occasions. Brown and Rice (1998) explained utility as the usefulness of the product and how well it conforms to end use standards. Features that represent utility as stated by Ratief and de Klerk (2003) include garment fit, comfort, ease of maintenance and appropriate functioning for the intended end use. Durability on the other hand, is described as the ability of a garment to maintain its structure and appearance after wear and care. A garment's durability however is determined by performance properties such as abrasion resistance, dimensional stability (shrinkage), seam strength, breaking strength and colourfastness (Retief & de Klerk, 2003). The

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performance properties that determine a garment's durability are inherent in the fabric or textile material used for the clothing item and the stitches and seams applied on the fabric. For example, good quality fabric will perform satisfactorily in terms of colour, shrinkage and strength as the right choice of stitches and seams for the particular fabric will determine the seam strength. This confirms Tselepis and Klerk (2004) view that the physical features influence the behavioural characteristics and that clothing consumers select clothing products because of the products' physical characteristics such as the fabric used for construction, stitches and seams (Figure 2.1). Consumers believe that these will cause specific behaviour.

For the purpose of this study, only certain intrinsic quality attributes regarding the physical features were examined. The attributes are fabric and construction (stitches and seams). Fabrics contain performance indicators such as fibre content and construction which are used to determine apparel quality (Fiore & Damhorst, 1992). For example, Fiore & Damhorst (1992) pointed out that weight and hand or feel of a fabric are strong indicators of quality in women's pants. They continued that a sign of high quality fabrics is comfort and a high thread count of the fabric is an indication of durability.

The wearable life of a fashion garment may be only a few weeks making intrinsic characteristics that affect durability less critical to acceptable performance (Glock & Kunz, 2005). On the other hand, basic garments with little or no change in style or design year after year such as school uniforms depend on intrinsic characteristics for better performance (Glock & Kunz, 2005). Standard specifications are therefore developed to ensure an appropriate combination of intrinsic quality characteristics,

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maintain quality throughout production, control cost and produce quality products (Glock & Kunz, 2005). Kadolph (2007) reported that specification or 'spec' is a precise statement of a set of requirements to be satisfied by a material, product, system or service and indicates the procedures for determining whether each of the requirements is satisfied. Standards on the other hand are a set of characteristics or procedures that provide the basis for resource and production decisions and are used to define the quality level characteristics and performance for a product (Glock & Kunz, 2005). Mehta and Bhardwaj (1998) also defined standards as something that is established by authority, custom or general consent as a model or example to be followed. They indicated that according to ISO, standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines or definitions of characteristics to ensure that materials, products, processes and services are fit for their purpose.

In the textile and apparel industry, product quality is calculated in terms of quality of fibres, yarns, fabric construction, colourfastness, and final finished products (Rahman, Baral, Chowdhury, & Khan, n.d). Due to these, quality control inspectors engage in various testing and inspection procedures by using standards and specifications to verify a product's quality level. As indicated by Rahman et al. (n.d) basically two methods are used for garment quality control which are testing and inspection. In order to ensure that apparel products such as school uniforms that reach the consumer including school pupils are of good quality, there is the need to employ testing and inspection procedures.

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2.3 Conceptual Framework for the Study

On the basis of the ongoing discussions and the extent of literature, a conceptual framework was developed to guide the current research and is presented diagrammatically in Figure 2.2, page 24. From the literature it is clear that the intrinsic attributes can be used to determine quality of an apparel product. As this research analysed fabric and seam performance properties, the work focused on the physical attributes of intrinsic quality cues which were fabric and constructional factors (stitches and seams) which in turn influence performance (durability). Good quality school uniforms depend on the quality of such intrinsic characteristics as fabric, stitches and seams for better performance.

The level of quality of fabrics and seams can be determined by their performance properties. The performance properties of fabric include strength, dimensional stability, weight and colourfastness to specific agents (Retief & de Klerk, 2003). The performance properties of the fabrics are influenced by factors such as the kind of raw material used (fibre type), yarn twist, yarn count, cover factor, type of dye and the fabric construction method. The range of the performance properties as indicated is wide and depends on the type of garments being studied, the study's aim, the wearing surroundings and the wearer (Masteikaitė et al., 2013). Masteikaitė et al. (2013) stated that the quality of school uniforms, more often, is characterised by physical (e.g. fibre type) and mechanical (e.g. strength) properties of fabrics used. Based on the determinants for fabric quality and suitability for a particular end-use, the fabric characteristics that were examined in this study were fibre content, thread count, weight of the fabric, tensile strength, breaking elongation, colourfastness, yarn linear density, shrinkage and absorbency.

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On the other hand, seam performance properties include strength, elongation, efficiency and slippage. The performance properties of the seams are also influenced by factors such as thread type, fabric type, stitch density and seam type. The performance properties of both fabric and seams interact with the processes garments go through during use such as washing to affect the overall quality of the garment (uniforms). The seam parameters examined in this study were strength, efficiency and elongation. The quality characteristics determined are shown in Figure 2.2, page 24, indicating the conceptual framework of the study.

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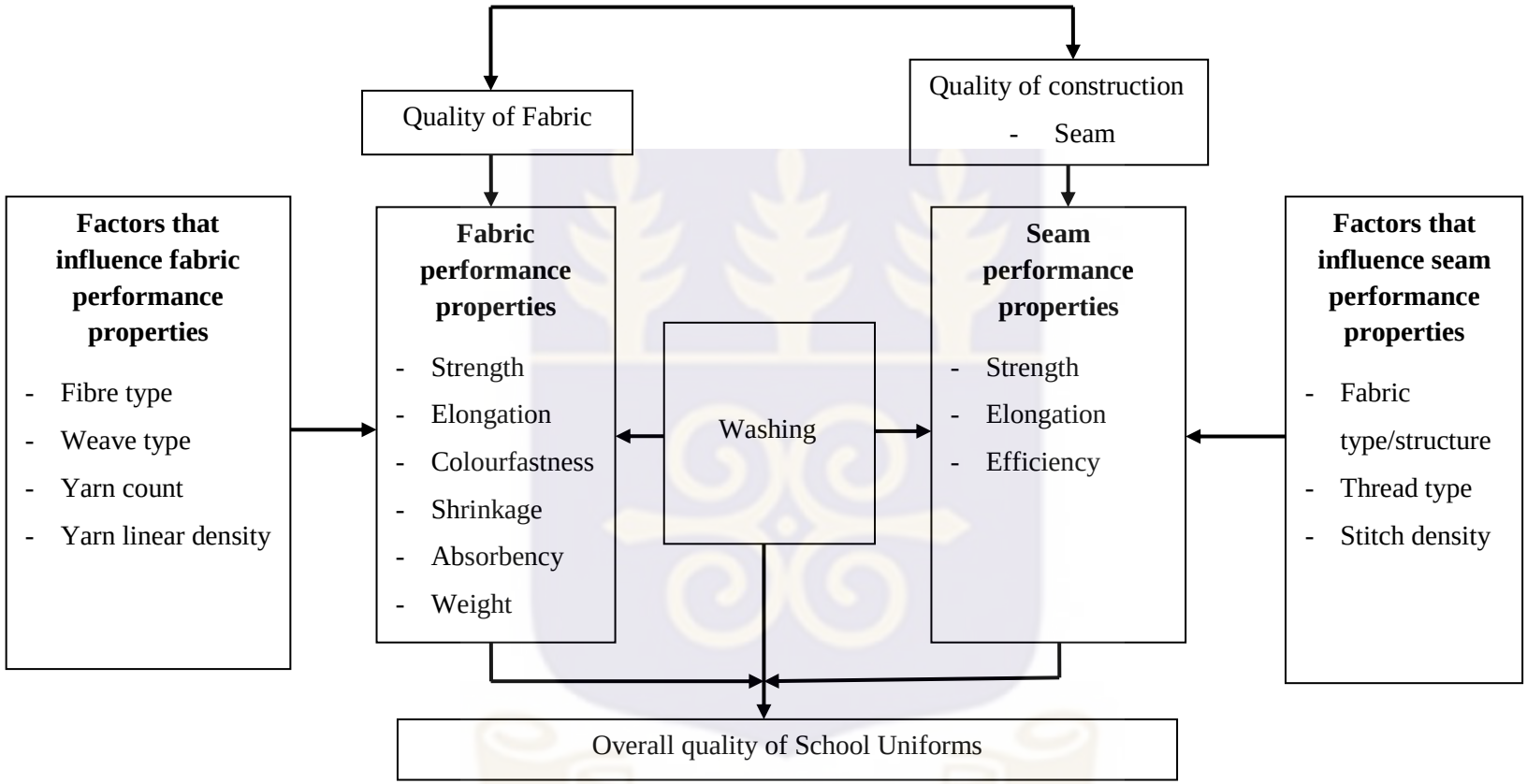


Figure 2.2: Fabric and Seam Performance Characteristics that Affect Quality of School Uniforms (Author's construct, 2016)

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SECTION TWO

2.4 Brief History of School Uniforms

Kantheti, Devi and Anitha (2015) explained school uniform as a set of standardized clothes worn primarily for an educational institution and are common in primary and secondary schools in various countries including Ghana. Brunsma (2004) recognised that there exists no definitive history on school uniforms. He however, provided an overview of instances that are used to trace the history of school uniforms. Brunsma (2004) indicated that school uniforms in contemporary public schools have their roots in the confluence of secular and religious influences that contextualized the earliest universities in Germany, France and England. Brunsma (2004) and McBrayer (2013) suggested that the root of uniform use can be associated with catholic schools. The earliest recorded use of standardized academic dress as indicated by Brunsma (2004) might have been in England in 1222, when the Archbishop of Canterbury mandated that students wear a rob-like outfit called the "Cappa Clausa". However, the modern school uniform can be traced to 16th century England, when the poor orphan boys and girls "charity children" attending Christ's Hospital boarding School were asked to wear blue cloaks resembling the cassocks used by Clergy along with yellow stockings (Brunsma, 2004).

Although, the introduction of standardized dress in schools came with much opposition by students and parents, the uniforms eventually were accepted (Brunsma, 2004). School uniforms were introduced due to the much more rigidly defined ideology of class and position steeped in symbolic imaginary of class and social status (Brunsma, 2004). According to Brunsma (2004), the move to uniform students,

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especially in England, was due to university students showing flamboyance in their dressing (what was worn indicated status symbol). He indicated that there was therefore the need for strict regulations on clothing. The initiative, Brunsma (2006) noted, was to help reduce the effect of social disparity, that is, to physically bridge the gap between the poor and the rich in their school system. In an article, "School, Uniforms, Academic Achievement, and Uses of Research", Bodine (2003) related the introduction of school uniform to same reason as indicated by Brunsma (2004). Bodine (2003) provided examples of school uniform programmes implemented in 1894 in an attempt to reduce social disparity. Bodine noted that in 1894 with the opening of Winthrop National and Industrial College, the implementation of school uniform was to do away with distinctions of wealth. High schools in Muncie, Indiana, United States of America in 1932 also proposed the use of uniforms with the aim to eliminate class distinctions and to physically make the poor and the rich equal in the school setting (Bodine, 2003). It must however be stated that though school uniforms are in existence in the world today, its introduction met much opposition.

According to Brunsma (2004), at the introduction of uniforms at Cambridge, students continuously resisted and challenged the definitions of what acceptable school attire was throughout the 16th century. Other opponents to school uniform policies as indicated by Gouge (2011) argued that requiring school uniforms violates students' rights and does not provide students the opportunity for individuality. This opposition notwithstanding, the practise of using school uniforms has since been adopted by many other countries and common in many parts of the world including Ghana.

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2.4.1 Introduction of School Uniforms in Ghana

In Ghana, pupils in government public basic schools use same type of uniforms with the school's emblem or badges used to distinguish among the different public schools available. However, private and mission schools in Ghana determine which uniforms their pupils wear. Although the exact date from which the introduction of uniforms began in Ghana is non-existent, Kadiadze (2014) noted that in the 1960s mission and local authority schools had their own style of school uniforms. The colours for the uniforms included blue and white and green and white. She continued that in the 1980s the Provisional National Defence Council (PNDC) government, however, made a change in the uniforms and all public-basic schools from primary to Junior Secondary Schools (JSS), now Junior High Schools (JHS)use the same type of uniforms with the fabric and style being the same. The colours of the fabrics used for the uniforms are sandy brown and chocolate brown. Each senior secondary school had its own type of uniforms for their students. The trend still exists in Ghana today. Figure 2.3 shows some public basic school pupils in their uniforms.



Figure 2.3: Some government public basic school pupils in Ghana in their Uniforms

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2.5 Importance of School Uniforms

Several authors on school uniforms have provided a number of reasons for the use of uniforms. Bodine (2003) indicated that school uniforms are advocated for a range of social, economic and educational reasons.

Social Reasons for the use of School Uniforms

In the view of MacBrayer (2013), uniforms foster school unity, bring about reduction of violence and behavioural problems, improve the learning environment, reduce social pressure and level status differentials. Thus, increases student self-esteem and motivation. A School uniform is considered to boost students' self-esteem (Gouge, 2011). As all students are dressed in common clothes external differences that might have led to one being teased as inferior and unfashionable, is eliminated (Gouge, 2011) generating a feeling of oneness and creating a sense of belonging. Kantheti, et al. (2015) noted that in response to growing levels of violence in schools, parents, teachers and school officials believe that school uniforms can help improve discipline, reduce youth crime, prevent formation of groups on campus, help easily in identifying intruders and thus increase school safety. This is because it is believed that a pupil in uniform can easily be identified, when he/she indulges in social violence. The uniforms enable authorities to observe and monitor the behaviour of the one wearing a uniform. Brookshire (2016) in a research on the impact of school uniforms on school climate observed that the climate of the school that had uniforms, was rated significantly higher than the one without uniforms. He noted reduced bullying, improved student learning and safety in the school with uniforms. Adams (2007) indicated that majority of teachers he studied viewed uniforms very effective in

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controlling school climate. Teachers claimed they saw improvement in students' behaviour with the introduction of uniforms (Adams, 2007).

Economic Reasons for the use of School Uniforms

Economically, school uniform is noted to help reduce economic and social barriers between students as well as minimize parental stress (Kantheti et al., 2015; The Irish School Wear Association, 2015). The Irish School Wear Association (ISWA) (2015) stated that the use of school uniforms reduces the pressure imposed on parents by children for particular and often expensive clothing. Again, since uniforms do not alter in style from year to year, students can wear uniforms for more than a year without the fear that they are out of style. This will save parents some amount of money and help pupils' to concentrate on academics and personal achievement rather than dress competition.

Educational Reasons for the use of School Uniforms

Educational importance of school uniforms include: increase in school enrolment and attendance and helping develop creative talents (Kantheti, et al., 2015; ISWA, 2015). The ISWA (2015) stated that a student in uniform who decides not to attend school for example, may be easily identified thus helping to curb truancy and attrition. In a research on "the relationship of school uniforms to student attendance, achievement, and discipline", Sowell (2012) noted that the school with uniform had significantly better attendance. According to the ISWA (2015), school uniforms help students to develop their creative talents as it is the nature of humans to express their own personalities. Since students feel the same in uniforms, the only way to express individuality is through talents and not clothes. This was noted to cause students to

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want to perform in specific areas such as sports, music, arts and or academics. Pate (1999) found significant improvement in academic achievement of students after implementation of school uniforms. Other researchers that have noted increase in school attendance and students achievement with the introduction of school uniforms include; a) Gentile and Imberman (2009) who observed modest improvement in language scores and attendance rates in middle and high school grades in the Southwest Houston and b) Agarwal (2015) who also found that wearing school uniforms in public schools result in positive effect on test scores, behaviour and attendance.

2.5.1 School Uniform Interventions

Government and Non-governmental organisations particularly those in the Sub-Saharan African countries recognising the importance of school uniforms have tried to provide free uniforms (Evans, Kremer & Ngatia, 2008) to reduce some burden of parents. It is noted that parents usually face many expenses for their wards education such as school fees and provision of uniforms (Evans et al, 2008). Pupils that do not put uniforms on or have tattered ones feel stigmatized (Evans et al, 2008). Evans et al. (2008) indicated that reducing the cost of schooling by providing uniforms, among other inputs, increases school participation. The government of Ghana as part of its poverty alleviation programmes and to increase enrolment in primary schools (reducing attrition rate), has intervened by providing, among other items, free school uniforms to basic school pupils in the government public schools in deprived communities. The programme is "Free School Uniforms for Needy Children in Basic Schools in Ghana". Modern Ghana News (19th January, 2010) reported that some pupils that received free uniforms provided by the government of Ghana indicated

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that without the uniforms they would have gone to school in torn uniforms or other garments, making their friends mock them resulting in truancy. The pupils said that wearing a good quality school uniform enhanced their stay and studies in school. Other pupils stated that psychologically, wearing a torn uniform had a negative effect on them as some of them were teased (Modern Ghana News, 19th January, 2010). The information reported by Modern Ghana News(19th January, 2010) show that good quality uniforms are needed so that the issue of poor students being stigmatized and parents spending more on uniforms will be eliminated. According to Bodine (2003), some Muncie students dropped out of school due to lack of desirable clothes and economically struggling Muncie parents had to pay more for school clothes than they could afford because they wanted their children to appear like the affluent parents' children. Bodine (2003) noted that the introduction of uniforms was to curb the issue of students leaving school due to lack of required clothes, but it must be noted that poor or inferior quality uniform can cause these same issues indicated by Bodine (2003).

2.6 Production of Public Basic School Uniforms and Quality Issues with Garment Production in Ghana

The style of the uniforms used by the government public basic schools in Ghana may be a skirt and blouse, a blouse and a pinafore or a dress for the girls. For the boys, it comes in a shirt and a pair of shorts. The girls' pinafore has two sections, the upper section and the lower section and is joined together with a waist band. The common features found on the government public basic school uniforms include: a collar, short sleeves, pleats, pockets, button and button holes, zippers, plackets and hems. The fabrics used for making the uniforms come in two different colours which are

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chocolate 4/saddle brown usually used for skirts, pinafore and a pair of shorts and sandy brown for shirts or blouses.

For school uniforms to function as intended, Encyclopedia of Clothing and Fashion (2005) pointed out that certain key elements should be considered. The elements include; a) the involvement of parents, teachers, school administrators and students in the selection of style, b) the uniforms should be affordable, c) fabrics used should be suitable to local weather conditions, d) the uniform should be durable to the extent that they can be traded and e) the style should fit all shapes and figure types. Ünal, Yildiz and Özdil (2011) also indicated that primary school students spend half of their days wearing school uniforms; therefore uniforms should meet expectations like thermo-physiological and tactile comfort. Ünal et al. (2011) added that since children are more active and sweat more than adults their clothes have to facilitate water vapour and liquid moisture to be transferred from skin surface to avoid possibility of illnesses. The uniforms should allow perspiration to be transferred to the atmosphere in order to maintain the thermal balance of the body (Ünal et al., 2011). School uniforms require fabrics that are strong, absorbent and easy to care for.

In Ghana, the government public basic school uniforms used by pupils are either custom-made. That is, a parent may purchase the uniform fabric and contract a garment maker referred to as seamstress or tailor to sew the uniform according to the specifications the parent or pupil gives. Or they are mass produced where the uniforms are manufactured in large quantities in various sizes and are purchased from the market. Some are supplied by the government through the free school uniform programme. The uniform manufacturers and parents may purchase any type of fabric;

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though in the prescribed colour, for public basic school uniforms that may not meet the Ghana Standards Authority standards for uniform fabrics. There are variations in the brands of fabrics used in the uniforms production and sewing parameters used for the uniforms such as stitch densities. The knowledge and skill of the producers of the uniforms are also questionable. Sarpong, Howard and Ntiri (2012) indicated, in their study on enriching the competency skills and knowledge of semi-skilled garment producers in Ghana, that garment producers within the study area (Cape Coast) had inadequate knowledge and competency skills for garment production. Ampong (2004)carried out a study in Cape Coast metropolitan centre about garment makers and Kuma-Kpobee (2013) also studied dress makers at three metropolitan centres (Accra, Kumasi and Takoradi) in Ghana; they noted that many manufacturers relied on old manual hand and treadle machines for production with hand sewing machines being dominant. Speed and quality were therefore compromised. It was further indicated by Kuma-Kpobee (2013) that most of the garment manufacturers over relied on semi-skilled trainee apprentices for garment production and this affected the level of quality of garments produced.

The issue of garment makers not following quality standards for garment production also exists. Kadiadze (2014), for example, stated that before school uniforms are produced at the Senior High School level, school authorities relied on visual and not on thorough examination of the quality of fabrics. The constructional details of uniforms were done without consulting experts for assistance. Kuma-Kpobee (2013) in her study on the evolution and current manufacturing practice applied to traditional dress for women in Ghana, also found that there were no standardized procedures followed by the garment manufacturers in the selection of sewing parameters such as

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stitches. However, Ampong (2004) emphasized that stitches and seams are very paramount in the construction of garments and required to be of good quality. She reported that garment manufacturers had problems with stitches and seams used in joining pieces of fabrics together. This, she indicated could be attributed to the lack of skills and knowledge in garment production as well as manufacturers not following required standards. For example, she observed problems such as varied stitch per inch (SPI), skipped stitches, loose formation and insecure stitch ends, which affect the quality of seams produced in terms of strength and efficiency.

Doshi (2006) pointed out that quality related problems in garment manufacturing like fabric defects, sewing defects such as open seams, wrong stitching techniques used and missed out of stitches in between should not be overlooked. However, in a research on "quality of construction processes and fit of government supplied uniforms in west Akyem Municipality", Koranteng (2015) identified sewing defects in the uniforms produced such as ripped seams, miss out of stitches and unfinished edges. The researcher of the current study also bought some mass produced uniforms from the market and found similar issues as indicated by Koranteng (2015), Ampong (2004) and Kuma-Kpobee (2013). The pictures in Figures 2.4 to 2.8 on pages 35 and 36 provides the visual representation of the construction issues found on some uniform garments purchased from the market by the researcher. Thus, indicating the need for research to help improve the quality of uniforms.

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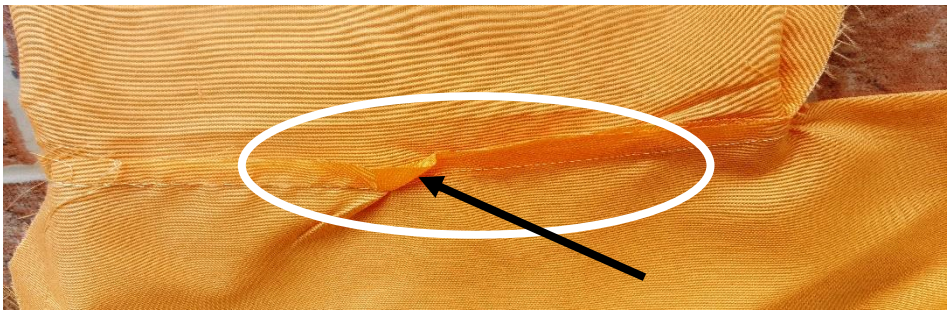


Figure 2.4: Seam puckers at the armhole of a shirt

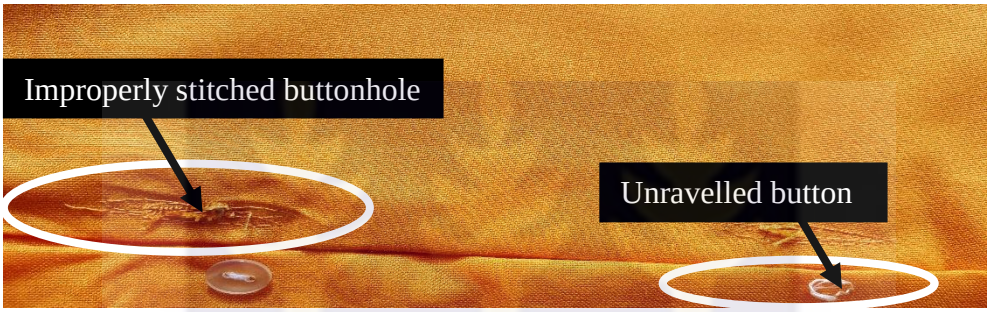


Figure 2.5: Improperly stitched buttonhole and unravelled button

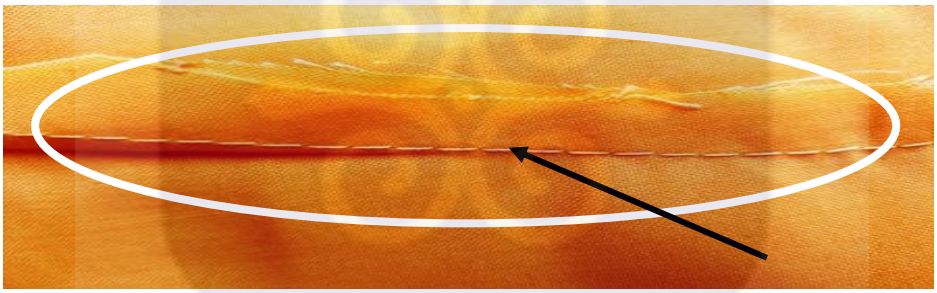


Figure 2.6: Long stitches of 7 stitches per inch (spi) at the armhole of a shirt

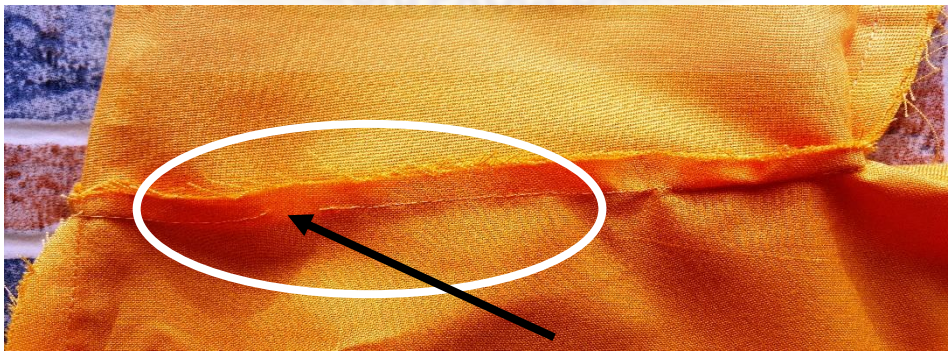


Figure 2.7: Ripped seam in a shirt that has not been worn yet

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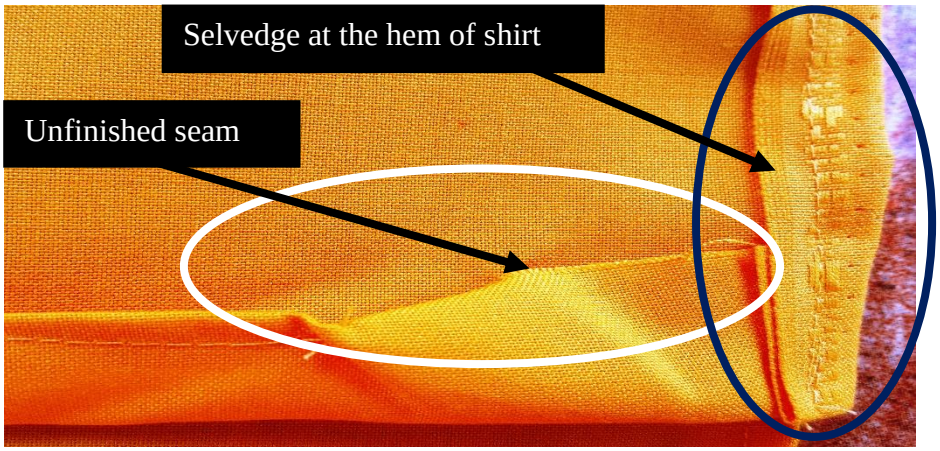


Figure 2.8: Raw edge showing due to incomplete stitching and selvedge at the hem of the garment indicating the garment was cut of-grain

SECTION THREE

2.7 Assessing Quality in the Textile and Apparel Industry

For industries or businesses, to increase sales and compete well among consumers and fellow companies, they have to maintain a level of quality of the products they produce. Quality may be defined as the level of acceptance of goods or services by consumers (Rahman, Baral, Chowdhury & Khan, n. d.). Conforming to specification is quality (Indi, n. d.). Talking about quality in the textile and apparel industry requires a look at the terms quality management, quality assurance and quality control. Quality management according to Rahman et al. (n. d.) is the aspect of the overall management function that determines and implements the quality policy, while quality assurance covers all the processes within a company that contribute to the production of quality products. Quality control, on the other hand, is the operational techniques and activities used to fulfil requirements for quality(Quality

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Gurus.com, 2011). In the textile and apparel industry quality control is practised right from the initial stage of sourcing raw materials to the stage of final finished garment (Alagulaskshmi et al., n. d.). Kadolph (2007) indicated that textile quality assurance is a process where companies design, produce, evaluate and assess their products to determine whether they meet the desired quality level for its target market. Quality is inherent and is incorporated into the product during product development, production and marketing (Kadolph, 2007). According to Kadolph (2007), a number of factors determine quality fitness of the garment industry. The factors include performance, reliability, durability, conformance, serviceability, aesthetics features and perceived quality of the garment. Quality needs to be defined in terms of a particular quality certification. Thus, international quality programmes like International Organisation for Standardization (ISO) 9000 series lay down the broad quality parameters based on which companies maintain export quality in the garment and apparel industry. Some of the main fabric properties that are taken into consideration for garment manufacturing for export basis are; overall look of the garment and colour fastness of the garment (Doshi, 2006). Rahman et al. (n. d.) indicated that basically two methods are used for garments quality control. The methods are inspection and testing.

2.7.1 Inspection as means of Quality Control in the Textile and Apparel Industry

Inspection in reference to quality control in the apparel industry can be defined as the visual examination of raw materials such as fabric, buttons and sewing threads used for the production of apparel in relation to some standard specifications or requirements (Glock & Kunz, 2005; Kadolph, 2007; Mehta & Bhardwaj, 1998). Inspection includes a physical check of product dimensions or measurements to

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determine whether the product is of appropriate size, shape or proportion with the eye and the use of a simple measuring device, such as ruler or template (Kadolph, 2007). According to Glock and Kunz (2005), inspection has three purposes which are to: a) determine whether products have been made according to specifications, b) determine if products meet set standards and c) to determine whether products are acceptable. Mehta and Bhardwaj (1998) provided an inspection loop which must be completed for inspection to be effective (Figure 2.9). The loop shows that the inspection process is cyclical and does not end at one particular point but moves on till quality products are obtained for the final consumer. Thus, aid in producing quality products that will meet consumer expectation and result in increase in profits and consumer loyalty.

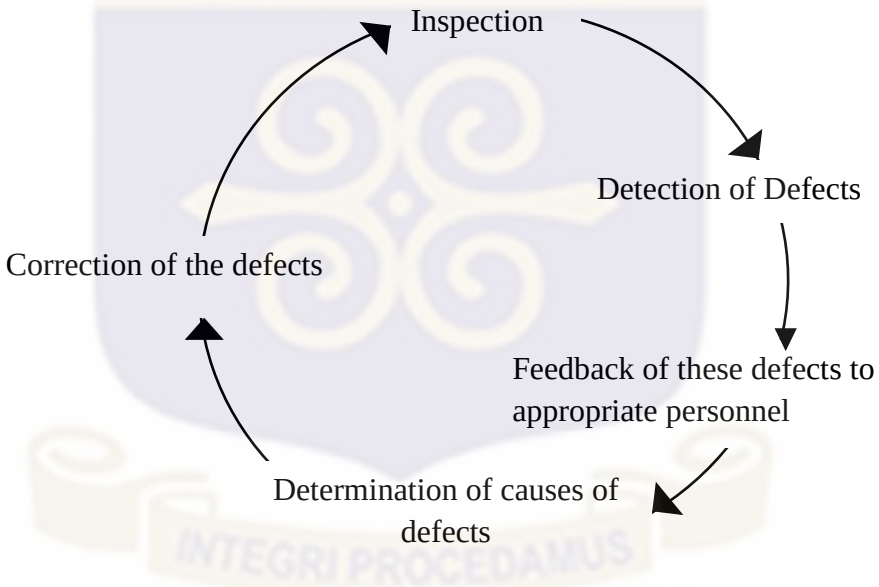


Figure 2.9: Inspection loop (Mehta & Bhardwaj, 1998)

The principle involved in inspection is the early detection of defects, feedback of this information to appropriate people, and determination of the cause, ultimately resulting in the correction of the problem (Figure 2.9)(Mehta & Bhardwaj, 1998). Inspection therefore requires an in-depth understanding of the precise nature of the requirements

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and expectations for the product and target market. There are inspectors that are trained and understand the measures used to assess performance of products and its ultimate success when used by consumers (Kadolph, 2007).

Different types of inspections are carried out during textile and apparel production to detect faults that may affect product quality. The types of inspection indicated by Mehta and Bhardwaj (1998) are: a) Material inspection b) In-process inspection and c) Final or product inspection. Kadolph (2007) reported that each inspection satisfies a particular need and is related to established criteria against which each material, component or product is to be inspected and when inspection is to be conducted during production. The discussion that follows focuses on the inspection types as they apply in the textile and apparel industry.

A. Materials Inspection

Materials inspection identifies the presence of any defect with the materials to be combined in a product (Kadolph, 2007). This type of inspection can be carried out at source or on the materials arrival at the buyer's warehouse (Kadolph, 2007). The materials inspected include fabrics, zippers, buttons, threads and interlinings. Some managers in the apparel industry believe that the relatively low cost per yard of fabric precludes the expense involved in materials inspection prior to spreading. Others recognize that the quality of the finished product can be no better than the quality of the goods that go into it, hence, the need for inspection (Glock & Kunz, 2005). As stated by Glock and Kunz (2005) and Kadolph (2007) quality cannot be inspected into products, but, has to be built into products. Inspection of materials helps build quality into products and decrease production cost (Kadolph, 2007).It is estimated that

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repairing finished garments costs 5 to 10 times as much as early detection of fabric defects (Jacobsen, 1985). Glock and Kunz (2005) provided some advantages and disadvantages of materials inspection. The advantages include: a) shortages are immediately detected, b) claims against suppliers can be processed immediately, c) suppliers can be evaluated, d) fabric utilization can be improved because exact cuttable measurements are known, e) materials wastes can be reduced, f) preproduction and production stoppages are reduced g) production productivity is improved h) costs are reduced by avoiding recuts, reworks and repairs and i) Customer satisfaction is increased. The disadvantages mentioned by Glock and Kunz (2005) were: a) time must be committed to the inspection process, b) specialised machines and personnel are expensive and c) space must be allocated for inspection.

B. In-Process Inspection

In-process inspection means the inspection of parts or components such as sleeves and collar of garments before they are assembled into a complete product (Kadolph, 2007; Mehta & Bhardwaj, 1998). The aim is to identify that each step in production has met specifications or of good quality before additional work is carried out on each component. Mehta and Bhardwaj (1998) added that this type of inspection is designed to uncover deficiencies in workmanship as well as equipment malfunction. Thus, in-process inspection can be used as a diagnostic tool to help refine and improve the production process (Kadolph, 2007). Mehta and Bhardwaj (1998) and Kadolph, (2007) continued that in apparel manufacturing, this means inspection at various points in the entire manufacturing process from spreading of fabric to pressing/finishing. A well run in-process inspection programme will result in reduction of major ‘surprises’ from customers due to bad quality, decrease in labour

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cost due to a decrease in repair rates and each operation performed correctly makes for a smooth running plant (Kadolph, 2007; Mehta & Bhardwaj, 1998).

C. Product Inspection

Product inspection involves a holistic visual analysis of the product to determine its adherence to requirements. Product inspection occurs after all production procedures have been accomplished. Final inspection ensures that the finished product meets required standards and specifications in terms of fit, size, design, construction and appearance (Kadolph, 2007). In some cases this is a final inspection after machining, with a general appearance check after pressing, as companies cannot let defective garments pass to their customers (Chuter, 2002). Final inspection is based on 100% of the products or on a statistical sample. The inspection is usually done at the production facility and in some cases at the distribution centre or shipping facility (Kadolph, 2007). According to Glock and Kunz (2005) finished goods inspection remains the most frequent type of quality control in apparel plants. Some apparel firms still use quality control systems that depend on 100% inspection of finished products (Glock & Kunz, 2005) to ensure that no poor work leaves the factory and thus products that leave their firms are of good quality.

2.7.2 Testing as a means of Quality Control in the Textile and Apparel Industry

Inspection alone cannot be used to assure consumers of quality. Therefore there is the need for the addition of testing procedures. As indicated by Kadolph (2007), subjecting products to physical or mechanical tests is very important in determining product quality. Mehta and Bhardwaj (1998) indicated that testing is a means of

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determining the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental or operating actions and conditions. Hu (2008) also stated that testing of textiles refers to various procedures for assessing different types of fibres, yarn and fabric characteristics such as fibre strength and fineness, yarn linear density and twist and fabric weight, strength, abrasion resistance, colourfastness and stiffness. It involves the application of engineering knowledge and science to the measurement of the properties and characteristics of, and the conditions affecting, textile materials and products (Hu, 2008). Grover and Hamby (1960) (as cited in Hu, 2008), noted that textile testing involves the use of techniques, tools, instruments, and machines in the laboratory for the evaluation of the properties of a textile or a textile product. Testing is conducted so that a material or product is evaluated in a controlled and planned manner.

Slater (1993) asserted that with advances in textile technology, combined with the rise in the number of knowledgeable consumers, it is essential for firms to understand the properties of a textile material or product and maintain the properties over a long period of time. Hu (2008) therefore indicated that there is the need for understanding the principles and procedures involved in testing, a certain degree of skill in carrying out test procedures and expertise to interpret reported results correctly. These are important steps in developing the ability to correlate structure with performance. The importance of testing as indicated by Kadolph (2007) and Hu (2008) include; producing results that aid in developing new products, improving current products, modifying standards and specification, assuring regulatory compliance, assessing the performance of textile materials and products and dealing with complaints. Testing of materials and products is done to select the most appropriate product or material

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especially where several similar items are available with standards and specifications as a guide (Hu, 2008; Kadolph, 2007). However, Pizzuto (2012) asserted that there is frequently a problem of directly correlating the laboratory test with the actual fabrics end-use, especially in the area of apparel. The reasons indicated include the fact that different people wear out their garments at different rates and fabrics being worn are usually subjected to repeated stresses which laboratory tests cannot duplicate economically such as a simultaneous combination of rubbing, bending and twisting.

It must however, be noted that although Pizzuto (2012) indicated that there is difficulty in correlating laboratory results with end use performance, Kadolph (2007) mentioned that research and experiences in the apparel industry has indicated that when minimum acceptable performance is met in laboratory tests, consumers tend to be satisfied with the performance of the textile product. It is very important to predict a textile fabrics performance by testing (Hu, 2008). Inadequate performance testing of materials can result in poor performance and unsatisfactory finished garments (Kadolph, 2007). Mehta and Bhardwaj (1998) for example, stated that a manufacturer lost $300,000 per year as a result of not testing a fabric before using it for production. This development makes it clear that testing is an important aspect of quality control. The testing procedure in itself does not help, but the interpretation of the test results help to identify problem areas that are required to be solved before the products reach the end consumer.

2.7.2.1 Systems Employed for Testing

Testing of materials or finished products can be done by employing different organizations (Kadolph, 2007). Hu (2008) indicated that currently there are large

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commercial organisations that have set up their own laboratories and standards to assess the quality of their products to satisfy their customers. On the other hand, there exists a vast majority of private and governmental testing organisations that test for materials and products as per the standard set on a commercial basis for the industries. In Ghana for instance, government and approved research organisations such as Ghana Standards Authority (GSA) is responsible to test and certify that a product's test results meet set standards. Thus, a test procedure on a textile material or product to judge performance can be carried out by the following methods:

a. Relying on the tests conducted by materials suppliers
b. Using the services of commercial laboratories
c. Establishing the firm's own testing laboratory
d. Using a combination of testing services (Glock & Kunz, 2005;Kadolph, 2007).

In this study, the Ghana Standards Authority (GSA) textile testing laboratory and the School of Engineering, materials science laboratory at the University of Ghana, Legon were employed.

Laboratory testing according to Kadolph (2007) is sometimes referred to as accelerated testing because the goal is to assess characteristics and performance quickly. Laboratory tests may be used for research, product development, end-use performance testing, materials or product analysis, certification, licensing agreements or performance assessment (Kadolph, 2007). It is assumed that the performance of the materials predicts the serviceability of the finished product. Methods and extensiveness of laboratory analysis vary widely among apparel firms. The amount and type of testing used on materials and finished products depends on the time frame for product development and a firm's emphasis on quality. Regardless of the source of

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testing, Glock and Kunz (2005) and Kadolph (2007) indicated that the use of standardized test method from bodies such as American Association of Textile Chemist and Colorist (AATCC), American Society for Testing and Materials (ASTM) and International Organisation for Standardization (ISO) is essential for correctly interpreting test results and for accurately communicating within the firm, with suppliers and customers, and with regulatory agencies. Testing procedures are carried out with the use of specimens (small pieces of the material cut or removed from a larger piece of fabric or a product) in a specialized facility. The procedures are conducted by trained technicians or specialists and majority of the equipment that is used may be specialized for each measurement of the material or product (Kadolph, 2007). When measuring resistance to abrasion, for instance, a piece of equipment is used that subjects fabric to conditions where abrasion effects are likely to occur.

2.7.2.2 Types of Testing

Kadolph (2007) identified two types of testing which are: a) materials and b) product testing. For materials testing, Kadolph (2007) states that, it involves the evaluation of each material used in a product to determine its characteristics, quality and performance. Such materials as the fashion or shell fabric (the fabric seen when the product is used or worn), interlinings, linings, trims, buttons, zippers, and much more are assessed separately. Materials' testing is important because customer satisfaction is based on the characteristics and performance of all materials used within a product. Hence quality and performance of fashion fabric and the other materials used in a garment are significant in producing goods that appeal to the target market (Kadolph, 2007). In addition, materials inspection helps companies to determine the nature, structure, and quality of materials for a product. This helps to combine appropriate

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materials into a single product. For instance, if a product includes a wool fashion fabric which has to be dry cleaned, other non-machine washable items, such as shoulder pads can be combined with it. Where materials with similar care requirements are used together, the potential for customer's satisfaction is assured (Kadolph, 2007). Furthermore, the information on the materials for production also helps companies to determine conditions of manufacture. If the materials are heat sensitive an acceptable temperature is identified during production (Kadolph, 2007).

With regard to product testing, the finished product such as a garment is the focus of assessment. Kadolph (2007) indicated that, fit, size and design may be evaluated using mannequins. However, to assess other performance parameters such as colourfastness, strength, seams and other constructional details, inspection and testing using laboratory analysis can be employed. Product testing helps to ensure that production or shipping lots meet standards and specifications. Kadolph (2007) further stated that, few products are selected from the lot and evaluated for appearance, construction and other selected measures to assure the consumer of product quality. In some cases, all products in the entire lot are assessed which is tedious and time-consuming. For product testing, laboratory testing can be carried out at a go for assessment or individuals may be allowed to use the product for a period of time for the product to be analysed. For example, prototypes can be given to a group of users to be worn for assessment or it can be a lifetime testing where the product remains in use till the user sees that it is no longer serviceable (Kadolph, 2007). Laboratory tests of a prototype or a finished product is faster and time efficient compared with life-time testing where some participants may not turn out and others might not follow the

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precautions needed which can introduce other variables likely to affect the results (Kadolph, 2007).

In sum, regardless of the type of inspection or testing carried out Mehta and Bhardwaj (1998), Kadolph (2007), Glock and Kunz (2005) and Chutter (2002) pointed out that testing and inspection can be 100% meaning all items in a production lot are inspected or tested or samples may be selected from a lot. Lot as used in the apparel business refers to a group of goods making up a single transaction. It may be a bundle, box or an entire production run from which a sample is taken and inspected for conformance with the acceptable criteria (Glock & Kunz, 2005; Mehta & Bhardwaj, 1998). For a product to be rejected it means it contained a number of defects. Defect is explained by Kadolph, (2007) as any non-conformance of a product with specific requirement. Example, where stripes are required to match at a centre front of a garment and they do not match, it is a defect which can cause a rejection of the particular product.

2.7.2.3 Types of Defects

In the textile and apparel industry defects are classified as being: a) minor, b) major and c) critical (Kadolph,2007; Chutter, 2002). With reference to critical defects, according to Chutter (2002), they are the defects that result in the product being scrapped. Kadolph (2007) added that critical defects results in hazardous or unsafe conditions for individuals a) using the product, b) maintaining or depending on the product or c) when the defect prevents performance of a critical function of a product. An example of a critical defect in glove is a hole or tear that allows the individual using it to come into contact with fluids-borne pathogen or disease.

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Concerning major defects, Chutter (2002) described them as those that prevent the product from being sold as a first class item, meaning one aspect is beyond tolerance. To Kadolph (2007) these types of defects are likely to result in product failure or reduce potentially the useability of the product for its intended purpose. With textile and apparel products, major defects are those that adversely affect either the appearance of the product or its function and performance. An example of major defect in a garment is when a zipper is not opening, or when a product is not able to function as the producer claims. For instance, a raincoat that does not shed water or that shrinks significantly when wet has a major defect. A poorly constructed seam in a garment is another major defect. Kadolph (2007) indicated that such defects are difficult to determine except through testing.

With regard to minor defects, they are those that are easily detected, but unless there are a significant number of them, such defect will not cause the product to be sold as a second (Chutter, 2002). Department of Defence (1989) (as cited in Kadolph, 2007) stated that minor defect is not likely to reduce materially the useability of a product for its intended purpose. For instance, a defect a company may describe as minor is when the left and right side of garment differ in width by only half an inch or one inch.

However, some companies have different interpretations for what is critical, major and minor defect. Some even may use the terms differently. A defect that renders a product totally unusable for example, may be described as serious rather than critical (Kadolph, 2007). Some companies may even have four levels for the description of defects depending on their own interpretation. The levels may be critical, serious,

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small and minor. What is deemed critical in one company may be deemed serious in another one. According to Kadolph (2007), some defects are zoned, especially on garments and the defects location or zone will determine whether it is major or minor or critical. A defect found on a product lining for example, may be deemed as minor but that same defect on a collar or centre front of the garment will be major or critical.

2.8 Standards and Specifications

2.8.1 Standards

Buyers are entitled to inspect and test goods to determine conformance to requirements before payments are made. However, specification and standard need to be written so that disagreements will not be difficult to be resolved (Kadolph, 2007). Based on this, various standard developing organisations exist around the world (Mehta & Bhardwaj, 1998). The organisations include; American Society for Testing and Materials (ASTM), American Association of Textile Chemist and Colorist (AATCC), American National Standards Institution (ANSI), British Standards Institute (BSI), and International Organisation for Standardization (ISO) (Glock & Kunz, 2005; Kadolph, 2007; Mehta & Bhardwaj, 1998).

In Ghana, the Ghana Standards Authority which is a government agency is also involved in the development of standards related to performance characteristics of products. Kadolph (2007) explained that standards are commonly agreed upon documents that assist in communication and trade. According to Mehta and Bhardwaj (1998), the International Organisation for Standardization (ISO) view standards as documented agreements containing technical specifications or precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that

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materials, products, processes and service are fit for their purpose. Standardization on the other hand is explained by Kadolph (2007) as the process of building and implementing regulations for consistent use in specific activities with the cooperation of all concerned. Some benefits of standards provided by Mehta and Bhardwaj (1998) and Kadolph (2007) include: a) standards can be used as marketing strategy to promote purchase of products that meet nationally recognized requirements, when conformance is backed by a certification programme. For example, a company may advertise its products indicating that the product is certified by the Ghana Standards Authority and b) Standards help reduce cost and save money. A company that complies with standards set for its product is assured that consumers will purchase its products and would be satisfied as standards present quality level and quality characteristics to enable a company meet target consumers' expectations (Glock & Kunz, 2005). Thus consumers will not waste money purchasing the product as it will perform satisfactory.

2.8.1.1 Levels of Standards

Producers, suppliers, manufactures, government agencies and consumers come together in the development of standards (Kadolph, 2007). They work together to be able to establish a criterion that will be accepted by all. Producers need to know the concerns of consumers, for example, when it comes to product performance in order to know the limits that need to be set for product quality determination. There are various levels of standards as indicated by Kadolph (2007) and Mehta and Bhardwaj (1998). The levels they indicated are Company, industry, Government and full consensus standards. However, Glock and Kunz (2005) also provided four levels of product standards as International, National, Industry and Company standards.

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Company standards may be developed by the company itself by doing extensive laboratory testing or the company may adopt one developed by an international body or another company and use as its own (Glock & Kunz, 2005). They are useful to the company's design development, production, purchasing and quality control department (Mehta & Bhardwaj, 1998). According to Kadolph (2007), a company's standards will reflect the level of performance required for its product. A company involved in the production of knitwear, for example, may decide to use reinforcing tapes in shoulder seams to minimize stress damage. These standards according to Glock and Kunz (2005) are established by companies through market research based on the predetermined preferences of target consumers, preferred quality characteristics, costs, price levels, and capability for sourcing and production. It is noted that apparel firms usually develop their standards for performance of product related to end-use. However, their standards may not meet consumer's expectations (Glock & Kunz, 2005). Glock and Kunz (2005) therefore indicated that product performance standards must meet the needs of both the consumer and the company involved in production of the particular product. This is because if consumers' expectations are not met the company's commitment to quality will not be realized. With regard to industry standards, they are developed by trade associations or professional societies and reflect consensus among many companies in an industry (Mehta & Bhardwaj, 1998; Kadolph, 2007). For instance, American Chemical Society has standards for chemical reagents used for production of textile products.

Government standards are either developed by the government or developed by other organisations and adopted for use by government. They generally tend to be related to safety or the well-being of consumers (Mehta & Bhardwaj, 1998). As indicated by

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Glock and Kunz (2005), government and trade supported organisations have developed performance standards for textiles and many other products for voluntary use. American Society for Testing and Materials (ASTM) and American Association of Textile Chemists and Colorists (AATCC), for instance, have established standards related to performance characteristics and physical parameters of textile products. Many apparel firms employ these standards to determine performance of materials (Glock & Kunz, 2005).

International standards on the other hand, describe a situation in which a number of products and services conform regardless of the products country or place of manufacture (Kadolph, 2007). According to Glock and Kunz (2005), international standards are very important for doing business in the global environment. This indicates that products that do not internationally meet set standards for performance cannot compete in the global market because such products are likely to be of poor quality and consumers will be dissatisfied with its use. International Standards are mandatory standards for business to thrive in today's market place (Glock & Kunz, 2005). The International Organisation for Standardization (ISO), for example, comprises national standard bodies from 91 countries and their published standards enable manufacturers to build and document an approved quality system that enables them to compete among their competitors in the global market (Glock & Kunz, 2005). The goal of International Standardization according to Kadolph (2007), is to make product development, production and sourcing more efficient and safe and in addition, minimize environmental impact.

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2.8.2 Specifications

Specification or 'spec' is a precise statement of a set of requirements to be satisfied by a material, product, system or service (Kadolph, 2007). Kadolph (2007) indicated that requirements mean that the expectation is non-negotiable, they must be met for the product to meet its end-use. Glock and Kunz (2005) also indicated that specifications (specs) are brief, written descriptions of materials, procedures, dimensions, and performance for a particular garment. Specifications provide specific terms and numerical values with measurement units listed to make clear issues considered important (Kadolph, 2007). For example, numbers are used in writing specs and the numbers address two important elements which are minimum and tolerance (Kadolph, 2007). For instance, if an abrasion resistance of a fabric is given a limit of 350 cycles as the minimum, it means anything less than 350 would not be acceptable. It is however pointed out by Kadolph (2007) that when a product meets or exceeds set specifications it is in conformance.

A tolerance according to Kadolph (2007) on the other hand, describes allowable deviations from specified values. For example, X±Y means a range from X to Y. The main problem with tolerance as indicated by Kadolph (2007) is that if a product or material consistently pushes to the lower limit for performance, the final product may not satisfy consumer expectations. Thus, many firms require that their products and that of vendors meet exact specifications indicated. Detailed specifications are used in the textile and apparel industry for: a) communicating specific product descriptions, b) developing products consistency and c) negotiation bids and contracts as the industry is more globalized now (Glock & Kunz, 2005).

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A fabric specification, for example, is a part of the legal purchasing document that specifies or states the performance levels of the fabric and the fabrics suitability for the end-use intended (Pizzuto, 2012). For instance, acceptable performance for a fabric in terms of dimensional change and colourfastness, appearance of seams and collars are specified in purchasing documents (Kadolph, 2007). Though standards and specifications are used to define and describe the quality of a product they significantly impact the cost of the final product (Kadolph, 2007). Specification indicating a high level of performance in terms of durability, the fabrics thread and other materials selected must meet their level of performance. The cost of such materials may be high and that increases the cost of the final product (Kadolph, 2007). However, since quality of products determine the success or failure of a company in business, standards and specifications for particular products must be adhered to.

For instance, the standard used by Ghana Standards Authority for determining the quality and suitability of uniform fabrics is GS 970:2009 (Textiles- specification for fabrics for shirts and uniforms). Examples of performance requirements for shirts and uniforms fabrics as indicated in GS 970:2009 include:

a) Fabric: the fabric could to be woven (W) or knitted (K) and made from cellulosic or synthetic fibres or their blends. The fibre composition is supposed to be designated as **C (**100% cellulosic fabric**), CR** (a fabric which is a blend of cellulosic and synthetic fibres and contains more than 50% cellulosic fibre), **SR** (a fabric which is cellulosic and synthetic fibres blend and contains less than 50% cellulosic fibre), **PE** (100% polyester), and **PA** (100% polyamide).
b) Defects: the fabric, when visually examined should be free from major weaving defects like slubs, torn selvedges and mis-picks.

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Tables 2.1 and 2.2 provide other performance requirements as indicated in the GS 970:2009.Table 2.1provides colour fastness requirements for cellulosic fabrics and synthetic fibre containing fabrics (minimum rating) and Table 2.2, page 56, presents requirements for woven shirt and uniform fabrics. It is indicated in the standard that a fabric shall be deemed to comply and of good quality if it meets all requirements stated.

Table 2.1: Colour fastness requirements for cellulosic fabrics and synthetic fibre containing fabrics (min. rating)

Fibre type	Washing				Colour fastness to perspiration		Light fastness	Water		Rubbing	
	Change in colour	Staining of			Alkali	Acid		Change of colour	Staining	Dry	Wet
		Cotton	Polyester	Polyamide							
C	3-4	3	-	-	3-4	3-4	4	4	3-4	4	3
CR	4	3-4	3	-	3-4	3-4	3-4	4	4	3-4	2-3
SR	4	3-4	3	-	3-4	3-4	3-4	4	4	3-4	2-3
PE	4	3-4	3	-	3-4	3-4	3-4	4	4	3-4	2-3
PA	4	3-4	-	3	-	-	-	4	4	3-4	2-3
Test method	GS ISO 105-C04:1989				GS ISO 105-E04:1994		GS ISO 105-B01/B02:1994	GS ISO E01:1994		GS ISO X12:2001	

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Table 2.2: Requirements for woven shirt and uniforms fabrics

Type of fibre	Mass per unit area (g/m^2)	Breaking Strength (N)		Tear strength Warp & weft (N) min.	Dimensional change on washing % (max)
		Warp	Weft		
C	>280	1000	650	30	±5
	235-279	850	550	25	
	190-234	700	350	20	
	140-189	350	300	-	
	<140	200	200	-	
CR	>280	1200	650	30	±2
	235-279	900	550	25	
	190-234	800	400	20	
	140-189	600	350	20	
	<140	200	200	-	
SR	>280	1300	750	30	±2
	235-279	1100	600	25	
	190-234	1000	500	20	
	140-189	700	400	20	
	<140	200	200	-	
PE, PA	>280	1300	750	30	±2
	235-279	1100	600	25	
	190-234	1000	500	20	
	140-189	700	400	20	
	<140	200	200	20	
Test Method	GS ISO 3801:1977	GS ISO	GS ISO 13934-1:2013	GS ISO13937-3:2000	GS ISO 5077:1984

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2.8.3 Test Methods

A test method is a definitive procedure for the identification, measurement and evaluation of one or more qualities, characteristics or properties of a material, product, system or service (ASTM, 2005,citedin Kadolph, 2007). Any test which has to be carried out on a product must employ standard test methods (Hu, 2008) so that the test result can be compared (Mehta & Bhardwaj, 1998). Hu (2008) also stated that the use of standard test methods in testing procedures makes every possible variable within the test method precisely controlled. In this way reproducibility is assured meaning a plant or laboratory test results will be same within the customer's laboratory to prevent lawsuits.

In the development of the standard test methods, precision and accuracy are important (Hu, 2008, Kadolph, 2007, Mehta & Bhardwaj, 1998). Precision is defined by Mehta and Bhardwaj (1998) as the degree of agreement within a set of observations or test results obtained by using a test method. It is the ability of the test method to produce the same results regardless of who conducts the test and where the test is conducted (Kadolph, 2007). Accuracy on the other hand, indicates the agreement between the true value of a property being tested and the average of many observations made according to the test method, preferably by many observers (Kadolph, 2007, Mehta Bhardwaj, 1998). This means that the result of the test must be a true reflection of the real performance of the material tested. To achieve precision and accuracy Hu (2008) mentioned that in most organisations involved in developing test methods, once the test procedure is clearly defined, it undergoes inter-laboratory trials. This can help reveal issues with the procedure and whether the method is applicable to a particular

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product. Table 2.3 presents some of the various parameters examined for assessing the quality of uniform fabrics and standard test methods used for testing.

Table 2.3: Some parameters used in this study to determine the quality of uniform fabrics

Parameters	Standard test used
Tensile strength and elongation of fabric	ISO 13934-1:2013
Weight of fabric	GS ISO 3801:1977
Dimensional change	GS ISO 3801:1977
Colourfastness to washing	GS ISO 105-CO4:1989

Standard test methods developed help industries in the textile and apparel business that import or export to foreign countries to obtain uniform specifications for products. Products exported to the United Kingdom for example, have to meet standards set by the UK regardless of the standards that exist in the country of manufacture. In the test methods, issues such as specimens' size to use, number of specimens to use and standard atmosphere for testing are addressed (Kadolph, 2007).

Kadolph (2007) and Mehta & Bhardwaj (1998) indicated that standard atmosphere for testing is defined as air maintained at a relative humidity of 65± 2 percent and a temperature of 21 ± 1^0C (70 ± 2^0F). This condition is required for testing because according to Kadolph (2007) and Mehta and Bhardwaj (1998), materials exhibit different performance behaviours under different environmental conditions. The reality is that moisture regained or lost to the environment can effect a change in their behaviour. Cotton for instance absorbs moisture rapidly when exposed to high

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humidity and as a result, the weight of the material as well as its strength increases and other properties change. With the application of standardized humidity and temperature conditions during testing regardless of the laboratory used, reliable comparisons can be made among different textile materials and products and among different laboratories (Mehta & Bhardwaj, 1998). The room that meets the standard atmosphere conditions for testing is also referred to as Standard Environment Room (SER) or Standard Environment Chamber (SEC) (Kadolph, 2007; Mehta & Bhardwaj, 1998).

2.9 Fabric Performance Testing

Fabric is the basic raw material for the production of apparel products (Bharani & Gowda, 2012). Performance is the ability of a product to meet the requirement and expectation of consumers (Glock & Kunz, 2005). Pizzuto (2012) explained fabric performance testing as involving formalized and exact procedures and also requires trained technical personnel and laboratory facilities for their undertaking. It was further indicated that after the fabric tests are conducted, the outcome is studied in order to determine whether the fabric is suitable for the intended end-use. Questions such as these arise after testing a) is the fabric strong enough to be used for men's trousers? and b) is the shrinkage of the shirting fabric considered excessive? (Pizzuto,2012). Answers to some of these questions determine the suitability of the fabric for the desired use (Pizzuto, 2012). According to Hussain, Malik and Tanwari (2010), all finished fabrics must conform to certain performance specifications depending upon their intended end-use. Certain fabric performance properties are used to determine their suitability for specific end-use conditions (Hu, 2008; Pizzuto, 2012). The performance characteristics indicated by Hussain et al. (2010) which are

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evaluated following standards of performance, which prescribe a required level of performance of materials (Pizzuto, 2012), include the type of fibre used, yarn linear density, fabric count, weave design, fabric weight, fabric breaking strength and colour. For example, a fabric must have a colourfastness to washing rating of, at least, a grade 4 (very good resistant to colour change) to be acceptable to a fabric buyer for a shirt manufacturer.

Glock and Kunz (2005) and Kadolph (2007) identified two general types of fabric problems which can be identified during performance testing. They are patent and latent defects. Patent defects are the visible variations in fabrics such as shading and fabric flaws including holes, stains and slubs. They further indicated that these defects are the ones that spreading operators are concerned with and can be readily seen or detected. Latent detects on the other hand, cannot be detected by simply viewing the fabric. They usually appear after the fabric has been further subjected to processes such as steaming, washing or pressing (Glock & Kunz, 2005: Kadolph, 2007). Common latent detects described by Glock and Kunz (2005) and Kadolph (2007) include shrinkage or stretching, poor colourfastness, sewability and strength. These latent defects mentioned by Glock and Kunz (2005) and Kadolph (2007) are also stated by Hu (2008), as being part of range of the fabric performance parameters or characteristics that are assessed for different end-use applications. It was further noted that fabrics are heterogeneous materials and the test results differ when a fabric specimen is tested in different directions (e.g. warp or weft, for wovens and course or wale for knits). Thus, the two directions of the fabric have to be examined to ascertain the overall quality of the fabrics involved. Mastiekaitè et al. (2012), for example, found in their study on the deformability analysis of fabrics used for school uniforms

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that the tensile strength in the warp direction was greater and attributed it to the fact; that there were great density of warp yarns per cm and they had higher twist which gave them higher strength to resist tension during the weaving process.

Wearing and dry-cleaning by consumers may also reveal some latent defects of the fabric and therefore fabrics have to be subjected to conditions they are likely to be exposed to during use to determine their overall performance. Glock and Kunz (2005) indicated that consumers are the ones that deal primarily with latent defects such as shrinkage and colour loss, as patent defects may have been removed at manufacturing stage. Thus patent defects are identified by inspection but latent defects can only be detected by testing the fabrics performance characteristics (Kadolph, 2007). Some fabric producers take responsibility for the evaluation of fabrics latent defects. Others also believe it is the responsibility of the apparel firm as they are responsible for the performance of the products they produce (Glock & Kunz, 2005). However, if the specifications are given to a fabric producer by an apparel manufacturer such requirements for the evaluation may be carried out and results indicated for the buyer to determine the quality level of the fabric before using to produce.

2.9.1 Performance Properties used to Determine Fabric Quality

The reasons why consumers discard their garments include; the fabric wearing out, the garment going out of style or because the consumer desires a new one (Pizzuto, 2012). Pizzuto (2012) however, stated that no matter the reason for discarding a clothing item what is expected by consumers is that the textile product must maintain good appearance and should not show undue signs of wear or fading, shrinking or stretching out of shape during its expected use life. For companies involved in the

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manufacture of clothing items to meet their profit margins they have to carry out tests depending on the end-use required of the product to meet consumer expectations of quality. Durability aspects expected of a textile product are high strength, high abrasion resistance, excellent colour retention and high seam strength (Pizzuto, 2012). Textile products that require maximum durability include utility work and uniform clothes, active sportswear and children's play wear which are subjected to high stress during wear and are utilitarian rather than fashion or style related (Pizzuto, 2012). Fabric performance properties testing are important since most fabric properties remain same when fabric is made into a garment (Mehta & Bhardwaj, 1998).Some of the performance characteristics used to determine fabric quality and suitability for particular end-use discussed in this study are:

A. Yarn Count of Textile Products

Yarn count which may be referred to as thread count or thread density is the total number of threads in both warp and weft or fill directions in a 2.5cm square (one-inch square) of woven fabrics or the number of wales or courses per 2.5cm square (one-inch square) for knit fabrics (Pizzuto, 2012). Pizzuto (2012) stated that ends and picks per 2.5cm square are definite indicator of fabric quality in terms of weight and strength. A higher thread count number means that there are more threads fitted within a 2.5cm square of that fabric and that can make a fabric stronger and resistant to shrinkage than one with less number of yarns (Kadolph, 2007). It was further indicated that in most end-uses, higher yarn count are preferable to a lower count for end-uses where durability is important such as in children's wear, active sportswear, uniforms and other similar applications (Pizzuto, 2012). Maqsood et al. (2016) noted increase in strength with increase in thread density. In a research on the analysis and

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improvement of trouser fabrics used for primary school uniforms, Ünal et al. (2011) found that the fabric with the highest weight and highest tensile strength also had high warp and weft counts and so attributed the weight and strength to the high yarn count of the fabric.

Although higher yarn counts provide positive effects in fabrics, some applications require lightest possible fabric consistent with serviceability such as lightweight summer shirts and blouses (Pizzuto, 2012). Research by Maqsood et al. (2016) has also shown that the greater thread density the lesser the air permeability of fabrics especially with synthetic fabrics. Ünal et al. (2011) also realized that the uniform fabric with the lowest yarn count had highest air permeability values. It must be stated that though the uniform fabric had lowest yarn count, it met their standard requirements for uniform fabrics.

B. Mass Per Unit Area (Weight) of Textile Products

Fabric mass per unit area often referred to as weight is an important factor decisive of fabric cost and quality (Kadolph, 2007; Pizzuto, 2012). Determining fabric weight is also important in order to determine whether the fabric is suitable for a specific end use (Pizzuto, 2012). As indicated by Keiser and Garner (2012) fabric weight must be compatible with the season for which the garment will be used, functional for the environment in which the garment will be worn and suitable for the style of the garment. According to Hu, (2008), weight measurement of a fabric is a prerequisite for subsequent tests of other fabric properties. Keiser and Garner (2012) stated that fabric weight and structure have implications for garment construction and cost for manufacturers. Lightweight fabrics for instance, may require a lining to make them

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opaque when worn, thus adding expense to the cost of the garment. Heavy or stiff fabrics work best in simple styles as they do not lend themselves to added fullness, such as gathers and will require heavier threads and needles and sometimes heavy-duty and special sewing equipment for construction. It must be added that the weight of the fabric also determines the stitch densities that can be used in stitching(Stamper, Sharp & Donnell, 1991). According to Stamper et al. (1991), high count, thin, lightweight, soft fabrics usually require at least 15 stitches per inch in order to be sewn securely. Heavy, coarse, low count fabrics, on the other hand, look better and are more durable when sewn with longer stitches. They argued that stitches that are too short might split the yarns of these fabrics and actually weaken the seam line. Brown and Rice (1998) (as cited in Chowdhary & Poynor, 2006) also identified fabric type and weight as the influencing factors to determine stitch density. They reported that lightweight and woven fabrics should be 15-18 SPI, medium weight fabrics 12-14 SPI and heavy-weight fabrics 6-10 SPI.

According to Pizzuto (2012) and Glock and Kunz (2005) usually fabric weights vary due to differences in fibre content, the number of yarns per inch as well as in yarn size. The weight of a fabric can be determined by a mass per unit area or a mass per unit length of fabric. Specimens of specific dimensions are taken by means of a cutting device or a template to obtain consistency in specimen size and weighed (Hu, 2008). The figures obtained are averaged to obtain the weight of the specific fabric or textile product. Testing is carried out in a conditioned atmosphere and results are commonly reported in grams per square metre (g/m^2) (Hu, 2008). The standards indicated by Hu (2008) that are used for testing weight include:

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a) ASTM D3376 – 96(2002) standard test methods for mass per unit area (weight) of fabric.

b) ISO 3801-1977 - Textile-woven fabrics-determination of mass per unit length and mass per unit area.

Table 2.4 presents range of fabric weights and examples of end-uses as indicated by Pizzuto (2012).

Table 2.4: Range of fabric weights and examples of end-uses

Weight type	Grams per square meter (g/m^2)	Examples of end-uses
Very lightweight	Less than 25	Curtains, sheer blouse, gauze, mosquito netting.
Lightweight	50 – 90	Lining, summer dress, shirt or blouse, summer pyjamas.
Medium weight	120 – 170	Summer suit, slacks, tablecloth, lightweight jacket.
Heavyweight	215 – 260	Winter suit, working clothes, towelling.
Very heavyweight	Over 350	Winter coat, heavy sweater, heavy canvas.

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C. Colourfastness to Washing of Textile Products

Colourfastness according to Mehta and Bhardwaj (1998) is the property of a dye or print that enables the print to retain its shade throughout the wear life of a product. Dyes are generally considered fast when they resist agents such as laundering and dry-cleaning to which they will be subjected to during use and care (Mehta & Bhardwaj, 1998). Colourfastness of Textile products is one attribute that greatly concerns consumers. According to Texanlab Laboratories Pvt. Ltd. Colourfastness Testing Series (n.d) the test for colourfastness to washing is one of the most basic colourfastness tests used by customers to evaluate end products. Mehta and Bhardwaj (1998) also indicated that consumer demand for fabrics with excellent fastness properties is of great concern to apparel manufacturers. In essence colourfastness determination of fabrics or textile products is required to establish how well the product will perform or maintain its colour (which is one of the first attributes that attracts consumers to products) during the end use of the product. The colourfastness tests also help to determine conditions that are likely to affect the colour of the fabric during use and indicated in care instructions accordingly. This probably informed the GSA to indicate colourfastness requirement for uniform fabrics as presented in Table 2.1, page 55.

Poor colourfastness according to Textile Machinery Network (2013) in the process of wearing, can affect other clothing items worn on the body or when washed (e. g. staining) and therefore affect such other items appearance and wearability. Lawal and Nnadiwa (2014) evaluated wash and light fastness of some selected printed fabrics. They noted minimal differences in wash and light fastness properties between the foreign and local fabrics they used for their study with the foreign fabrics showing

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higher fastness property both to washing and light as compared to the local fabrics. Ünal et al. (2011) observed in their study on analysis and improvement of trouser fabrics for primary school uniforms that colour change on washing values of all the fabrics they studied was acceptable. It was also noted that staining properties of the fabrics were good except for cotton.

The ISO grey scale for colour change is usually employed in assessing the colourfastness properties of textile products. The scale consist of nine pairs of standard gray chips, each pair representing a difference in colour (shade) or contrast corresponding to a numerical fastness rating. The results of colourfastness tests are rated by visually comparing the difference in colour represented by the scale. The assessment is done by using part of the original fabric and a tested specimen. These two are placed side by side in the same plane and oriented in the same direction. The Grey scale is placed nearby in the same plane. The visual difference between the original and tested fabric is compared with the differences represented by the grey scale. The fastness rating of the specimen is that number of the grey scale which corresponds to the contrast between the original and tested fabric. The rating is from 1 to 5 with a rating of 5 indicating no difference in the colour between the original fabric piece and the tested specimen and 1 being very poor colourfastness (Mehta & Bhardwaj, 1998; Kadolph, 2007).

D. Tensile Strength (breaking force and elongation) of Textile Products

Fabric strength properties (breaking force and elongation) are mechanical properties that are important for all textile users including processors, garment manufacturers, designers and customers (Hu, 2008; Wu & Pan, 2005). The elongation is the

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extension at break and extension is defined as the change in length of a material due to stretching (Hu, 2008). Elongation describes the increase in specimen length that had occurred up to rupture and it is usually expressed in percentage (Kadolph, 2007). Tensile strength is the strength of a material under tension and is expressed in terms of force (Kadolph, 2007). Breaking strength or breaking force is the force needed to rupture a fabric. Considering the strength of a textile product (e. g. fabric) is essential when selecting such products for the intended end-use. Mehta and Bhardwaj (1998) indicated that consumers along with other properties of apparel and textile items consider strength properties important. Strength determination of textile products help to establish whether the product will be able to withstand the processes it will have to go through for example dyeing, stitching and pressing to reach it final product and still maintain the level of strength required for the end-use(Mehta & Bhardwaj, 1998). Fabrics for children's garments for example, need to be strong as children's activities include play and since the garment will go through frequent washing procedures.

According to Mehta and Bhardwaj (1998) and Ünal et al. (2011), the strength properties of apparel have traditionally been considered the most obvious indicator of the service life of apparel. Wear life of a fabric correlates to both fabric strength and elongation (Pizzuto, 2012). Pizzuto (2012) stated that all other factors being equal, a fabric with lower breaking strength but higher elongation may remain wearable for long period same as a fabric with higher breaking strength but lower elongation. However, she noted that the extra elongation helps the fabric to better withstand the forces of normal wear. The factors that help create a strong fabric include, fibre content, yarn size and type, weave and yarns per inch (Pizzuto, 2012). For example, a

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100% polyester fabric with heavier yarns, plain weave and relatively high yarns per inch would be inherently strong. Mehta and Bhardwaj (1998) divided the strength properties of apparel into three areas which are:

a. Fabric strength
b. Seam strength
c. Resistance to yarn slippage.

In addition, fabric strength can also be divided into three areas: its resistance to tensile force (Breaking strength), its resistance to tearing/shearing force (tear strength) and its resistance to bursting force (bursting strength). Whether the strength of the fabric is measured in all these areas will depend on the type of fabric and its end-use (Mehta & Bhardwaj, 1998). Ünal et al. (2011) observed higher tensile strength in the warp direction than in the weft direction. Mastiekaitè et al. (2013) noted that most often the tensile strength in the warp direction is higher since there is greater density of warp yarns and warp yarns usually have a higher twist which makes them able to resist tension during the weaving process. In a study on deformability analysis of fabrics used for school uniforms, Mastiekaitè et al. (2013) found that the degree of elongation at maximum force for the tested fabrics was not greatly different. In addition, varied breaking force values for three tested directions of polyester fabric were noted. Ünal et al. (2011) also found that the bursting strength values of 100% PET and 97% micro PET – 3% elastane fabrics they employed for a study on the properties of knitted upper clothes used by primary school children was higher whereas fabrics containing 100% viscose had lowest bursting strength values. The standards commonly used for tensile strength test include:

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a) ISO 13934 – 1:1999 currently ISO 13934 – 1:2013 Textiles- Tensile properties of fabrics – part 1: Determination of maximum force and elongation at maximum force using the strip test method.
b) ISO 13934-2:1999 Textiles- Tensile properties of fabrics – part 2: Determination of maximum force using the grab method.
c) ASTM D5034 – 95 standard test method for breaking strength and elongation of textile fabrics (grab test).
d) ASTM D5035 – 95 standard test method for breaking strength and elongation of textile fabrics (strip test).

Ünal et al. (2011)employed ISO 13934-1 for testing tensile strength properties. Wu and Pan (2005) made use of ASTM D5034-95 and ASTM D5035 – 95 for their tensile strength experiments.

E. Dimensional Stability of Textile Products

Dimensional change is explained by Kadolph (2007) as either an increase in dimensions (growth) or a decrease in dimensions (shrinkage) of a textile product or material. Kadolph (2007) stated that poor dimensional stability can create problems with fit, size, appearance and suitability for end-use. It was noted that shrinkage is more common in consumer use. The measured dimensional stability of a fabric determines whether a fabric has the potential to retain its original shape and remain stable, indicating it will not bubble or sag over time, when applied over a substrate, and its suitability for a specified use (Islam, 2014). According to Mehta and Bhardwaj (1998), consumers consider the dimensional change in a garment to be a critical performance characteristic. The excessive shrinkage or growth of a garment can make that item unwearable.

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Mehta and Bhardwaj (1998) reported that a survey of apparel manufacturers indicated that fabric shrinkage rated one of the ten leading quality problems regardless of the size of the company interviewed. Garment shrinkage according to Mehta and Bhardwaj (1998) occur at three levels; fibre, yarn and fabric. They indicated that the total observed shrinkage is the resultant shrinkage of the three levels and the contribution of each to the total depend on fabric and yarn structure as well as the nature of the fibre. In cotton fabrics for example, shrinkage occurs principally at the fabric level and so sanforizing which is a preshrinking process can be done on cotton fabrics. However, rayon fabrics exhibit shrinkage at the fibre and yarn levels for this reason sanforizing is not effective on rayon fabrics. In a research on the effect of warp and weft variable on fabrics shrinkage ratio, Kadi and Karnoub (2015) noted that variables that affect fabric shrinkage ratio towards the weft include warp count and variables that affect fabric shrinkage ratio towards the warp include weft count. The causes of shrinkage as outlined by Mehta and Bhardwaj (1998) include;

1. Relaxation: it is noted that when yarns are woven into fabric, they are subjected to considerable tensions, particularly in the warp direction, although the filling (weft) yarns are also stretched. In the subsequent tentering and calendaring operations, this stretch may be further increased and temporary set in the fabric. The fabric is then in a state of dimensional instability. When it gets wet thoroughly, it tends to recover dimensional stability, which results in a contraction of yarns, giving rise to what is termed relaxation shrinkage. The contraction in the filling direction is normally considerably less than in the warp direction, although in some fabrics it can be high enough to cause complaint.

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2. Swelling: this shrinkage results from swelling and deswelling of fibres because of the absorption and desorption of water. In a loosely woven fabric, the effect of this swelling of the yarns is greater than in a tightly woven fabric, since there is greater freedom of movement.
3. Felting: this shrinkage occurs primarily from frictional properties of the component fibres which cause them to migrate within the fabric/yarn structure. This usually occurs to fabrics with scales on their surface, such as wool.
4. Contraction: this is the decrease in length that usually takes place in synthetic yarns/fabrics when they are exposed to temperatures higher than 21^{o}C (70^{o}F). Heat-setting however, can help almost eliminate the tendency of this shrinkage in synthetic fabrics. Apart from laundering, steaming and pressing can also result in contraction shrinkage in synthetic fabrics (Mehta & Bhardwaj, 1998).

F. Fibre Content of Fabrics

A fibre is an individual fine hair-like structure that forms the initial building blocks of textile fabrics and governs the physical and chemical properties of the ultimate fabric (Pizzuto, 2012). Pizzuto (2012) stated that though fabric properties may be modified as for example crease-resistance finishes for cotton, nevertheless a fibre that is not suitable for a particular end-use will fail either at the beginning of production or during use. According to Kadolph (2007), identifying the generic fibre types present in a fabric and their percentage by weight helps determine characteristics that are important in handling of materials, temperature concerns related to pressing and finishing steps and product finishing steps. Kadolph (2007) continued that fibre content influences many characteristics of the product that are important to the customer. Characteristics indicated include strength, shrinkage, abrasion resistance

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and absorbency. The fibre content of a fabric usually determines the end-use required of that fabric. Pizzuto (2012) for example, noted that if a soft, absorbent fabric is required for men's undershirts, cotton would be excellent, but nylon would be undesirable. However, for a skin-jacket shell where great strength and wear resistance are required; nylon fibre would be good choice whereas cotton would not.

Fibres are classified as either natural (those found in nature) or manufactured (Glock & Kunz, 2005; Keiser & Garner, 2012; Pizzuto, 2012). According to Pizzuto (2012), all the fibres from both natural and manufactured have identifiable characteristics that can be viewed as assets or unfavourable depending on the intended end-use of the fabric to be made from the fibre. Due to these differences in performance properties of the different types of fibres, blends (a blended yarn is made of two or more fibres types) and mixtures (a mixture of a fabric compose of two or more different types of yarns) are made so that desirable properties in one fibre will improve the other (Pizzuto, 2012). For example, for a blend or mixture of cotton and polyester, whiles cotton will be enhancing absorbency of the fabric polyester will enhance strength and resiliency of the fabric.

In determining the fibre content of fabrics, two types of methods are indicated by Textile Exchange (2017). They are non-technical and technical tests. The non-technical tests include the feeling and burn tests. The technical test identified include; microscopic and chemical tests. The technical tests were noted to require technical knowledge and skills and are carried out in laboratories. The technical tests are however, much more reliable as compared to the non-technical tests because for example cotton and linen may behave the same way during burning test and can make

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it difficult to distinguish between the two. Again blends and the addition of finishes to fabrics can also make non-technical tests unreliable (Pizzuto, 2012). Kadolph (2007) however provided two other procedures used for fibre identification which are qualitative and quantitative procedures.

The qualitative procedure, Kadolph (2007) noted, involves the use of several techniques until enough information is obtained to make reasonable assessment as to the fibre type or types present in a fabric. The techniques used under the qualitative analysis include the use of microscope called microscopy, solubility, spectrophotometry and burn tests. Microscopy was noted to be the best way to identify natural fibres. Under this technique, the cross-section and longitudinal sections of fibres are observed with the use of microscope. For example, the convolution of cotton and its cross-sectional shape helps to identify it under the microscope (Pizzuto, 2012). Solubility involves the use of chemical solvents to determine whether a fibre is soluble, insoluble, forms precipitate or a plastic mass in the solvent (Pizzuto, 2012). Solubility in the view of Kadolph (2007) is not good for identifying natural fibres as it cannot distinguish between fibres of similar chemical nature; for example, fibre of wool and mohair exhibit same solubility behaviour, same as cellulosic fibres such as cotton and flax. Spectrophotometry produces a visual representation of the fibres molecular component by the use of wavelengths. For the burn test, a small piece of the fabric is placed in a pair of tweezers and brought toward a flame. Fibre behaviour as the fabric piece approaches the flame, the way it burns, the odour and colour of flame it produces as well as the type and colour of ash are compared to a table indicating how each fibre behaves under such conditions to identify the fibre type (Kadolph, 2007; Pizzuto, 2012). Cotton, for example, burns

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only, smells like burning paper, leaves or wood and leaves a residue of fine feathery gray ash.

With regard to the quantitative procedures, the percentages of fibres present in a fabric by weight of the generic fibre present in blends are determined (Kadolph, 2007). Some of the test methods identified for quantitative procedures include AATCC 20 – fibre analysis quantitative and ISO 1833 Textiles: quantitative chemical analysis. Three techniques are used under the quantitative procedure for fibre analysis. They are (a) chemical analysis by use of solvents (e. g. cotton, flax, rayon can dissolve in sulphuric acid of 70% concentration at 38ºC, Pizzuto, 2012), (b) mechanical separation which is used for mixtures in which yarns of different generic fibres are present in a fabric e. g. one fibre type may be used in the warp direction and a second type in the filling direction (e. g. cotton weft and polyester warp), and (c) microscopic techniques. In each of the procedures, the first step is to dry and weigh a specimen. For the chemical technique, individual components of a fabric blend are dissolved in a required chemical solvent. After dissolving, the remaining fibre is washed, dried and weighed. The percentage of each fibre type present in the specimen is calculated using the equation: Fibre dissolved, % dry =100 (F – G/F). Where F is the original dry specimen mass (g) and G is the extracted dry residual mass (g). In the case of the mechanical separation, the analyst physically separates the components, dries them, weighs and calculates the percentages based on the original weight of the specimen. Equation used is fibre type 1, % dry = 100 (A/B) where A is the dry specimen mass (g) of fibre 1 and B is the original dry specimen mass (g). For the microscope technique, the analyst counts the number of fibres of each identifiable type present in a specimen. This technique is employed when fibres cannot be

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separated by the chemical technique, but differ in microscopic appearance such as cotton and ramie blend. Percentages are calculated based on the number of each fibre type counted, the average fibre diameter and each fibre's specific gravity (Kadolph, 2007).

G. Yarn Linear Density of Fabrics

Yarn linear density is explained as a system of denoting the fineness of a yarn by weighing a known length (National Programme on Technology Enhanced Learning (NPTEL), 2011).Science Dictionary (2017) also described linear density as the weight of a fixed length of textile yarn. The smaller the number the finer the thread. According to NPTEL (2011), there are two systems of expressing linear density of a yarn. They are the direct and indirect systems. The direct system of denoting linear density is based on measuring the weight per unit length of a yarn, it is a fixed length system. The finer the yarn the lower the count number. In relation to the indirect system, it is based on measuring the weight per unit length of a yarn, it is a fixed weight system and the finer the yarn, the higher the count number.

Yarn linear density determination is important as it influences several fabric performance properties such as strength, comfort in relation to yarn permeability, absorption, water vapour permeability, weight and resiliency. Comfort, for example plays an important role in the selection of apparel (Chidambaram, Govind & Venkataraman, 2011). In a research on the effect of yarn linear density on mechanical properties of plain woven Kenaf reinforced unsaturated polyester composite, Saiman, Wahab and Wahit (2014) found that the mechanical properties such as tenacity of the composite increased when the yarn linear density increased. They indicated that the

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linear density of a yarn is also influenced by the amount of fibre incorporated in the yarn. Thus higher linear density of a yarn means that the amount of fibre loaded inside the yarn is high. Babu, Senthilkumar and Senthilkumar (2015) observed in a research on the effect of yarn linear density on moisture management characteristics of Cotton/polypropylene double layer knitted fabrics that finer polypropylene with coarser cotton yarn fabrics shows longer time to reach saturation point. This implies that such a fabric absorbs better than a fabric made up of all fine yarns. Baldua, Rengasamy and Kothari (2016) noted that linear density per filament affected fabric resiliency in their study on the effect of linear density of feed yarn filaments and air-jet texturing process variables on compression properties of woven fabrics. Again Senthilkumar, Sounderraj and Anbumani (2012) also noted that the effect of spandex linear density on dynamic work recovery (DWR) of the fabric was significant at both wale and coarse directions. They noted, for example, that yarn weight increases with increase in spandex linear density and resulted in increase of areal density of the fabrics they studied.

H. Fabrics Absorbency

Absorbency is described by Pizzuto (2012) as the ability of a fibre or fabric to take in moisture. Fibres and fabrics able to absorb water easily are called hydrophilic. All natural fibres are hydrophilic as well as three of the manufactured fibres, rayon, acetate and lyocell. On the other hand fabrics that have difficulty absorbing water and are able to absorb small amounts are called hydrophobic. All the manufactured fibres besides rayon, lyocell and acetate are hydrophobic. There are other groups of fibres that absorb moisture without feeling damp such as silk and wool. Such fibres are termed as hygroscopic fibres (Pizzuto, 2012).However, blends and mixtures of

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hydrophilic and hydrophobic fibres can help improve fabric absorbency. As observed by Das, Das, Kothari, Fanguiero and Araujo (2009) water vapour permeability and absorbency of a fabric increases with increase in number of hydrophilic group in a blend or mixture. Fabric absorbency influences many conditions of use including skin comfort. Where a fabric absorbs just a little amount of perspiration it can result in a clammy feeling (Pizzuto, 2012).

According to Kadolph (2007), moisture absorption is one of the key performance criteria in today's apparel industry, which decides the comfort level of the fabric. Clothing should possess good water vapour as well as liquid moisture transmission property as liquid transporting and the drying rate of fabrics are two vital factors affecting physiological comfort of garments (Das, Das, Kothari, Fanguiero & Araujo, 2009; Maqsood et al., 2016).According to Das et al. (2009), moisture regain and water absorbency of a fabric determines how much sweat can be absorbed by a garment from the skin. Kadolph (2007) noted that absorbent fabrics tend to be used for garments that are in direct contact with the skin such as pants and singlet, garments designed for exercise and warm weather conditions such as in the Ghanaian climates. This is because such fabrics are able to absorb perspiration and dry easily helping keep the body cool. To Quora.com (2017), the best fabric to wear for warm weather and super humid climates to maintain homeostasis should weigh 140 -160g/m^2. Das et al. (2009) observed that the human body perspires in liquid and vapour forms and to be comfortable they noted that clothing worn should be able to allow both types of perspirations to transmit from the skin to the outer surface. This is very important as individuals in the tropics such as Ghana, and pupils perspire a lot due to their activities involving play and the weather conditions. Absorption property of a fabric is

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influenced by the fibre used for the manufacture of the fabric as well as the yarn linear density of the fabric. In a research undertaken by Babu et al. (2015) on the effect of yarn linear density on moisture management characteristics of cotton/polypropylene double layer knitted fabrics it was revealed that as the polypropylene yarn fineness increases, water absorption time increases. In addition, finer polypropylene with coarser cotton yarn fabric showed longer time to reach saturation point.

The absorbency of a material (e. g. fabric) can be analysed in terms of how quickly they absorb liquid and the quantity they have absorbed when reaching saturation point(Kadolph, 2007). A fabric or material is said to be saturated when it cannot absorb any additional moisture. At the saturation point, excess water may pool around the material, settle on the top surface or pass through it (Kadolph, 2007). Some standard test methods used for testing absorbency as described by Kadolph (2007)include;

i. ASTM D 4772 – surface water absorption of terry fabrics. This is specific for evaluating terry towelling absorbency property.
ii. AATCC 79 – absorbency of bleached textiles. This is used for evaluating absorbency of dyed, printed or bleached fabrics. In this method a single drop of water falls onto a conditioned specimen held under tension. The time in seconds for the drop to lose its specular reflection is recorded.

Manufacturing Solutions Center (2017) provided another method which is AATCC/ASTM test method TS-018. This test method is designed to measure the water absorbency of textiles by measuring the time it takes a drop of water placed on the fabric surface to be completely absorbed into the fabric.

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2.10 Seams in Garments

Seams are the basic element of structure of any garment, consumer and industrial textiles (LaPere, 2006). Seams are formed when two or more pieces of fabric are joined by stitches (Glock & Kunz, 2005; Keiser & Garner, 2012). Stitches and Seams are two important basic constituents of the structure of a garment (Akter & Khan, 2015). Whiles stitches are used to join garment components together, seams give the shape of the garment (Akter & Khan, 2015). Chowdhary and Poynor (2006) asserted that selection of stitches and seams form an integral part of producing a good quality garment. The distance between the row of stitching and the edges of the fabric is termed as seam allowance (Glock & Kunz, 2005; Keiser & Garner, 2012). The width of the seam allowance provide fabric for alterations and is one factor for judging garment quality and reducing seam slippage (Glock & Kunz, 2005). LaPere (2006) noted that seam allowance should be satisfactory for the durability of home furnishings or apparel products.

However, Heaton (2003) indicated that, unless otherwise stated, a seam is stitched 5/8 of an inch from the cut edge. Although other methods are used in joining textile products such as gluing and bonding (LaPere, 2006), LaPere (2006) and Kadolph (2007) indicated that the use of thread in stitching garment pieces together is the principal method. AMANN Inc. (2009) noted that seams are always decisive for the product quality, since they contribute to the beauty and function of the apparel product. A broken seam on a sofa, a ripped seam on curtains or a weather-related torn seam on a sunshade ruins the product's quality as a whole. Reworking or replacing such problems is often time consuming and often very expensive as well. According to Choudhary and Goel (2013), in good quality garments, seams are very important

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for the life and serviceability of the garment. As indicated by Choudhary and Goel (2013) and Mukhopadhyay, Chatterjee & Ahuja (2014) the major purpose of a seam is to provide uniform stress transfer from one piece of fabric to another as a result protecting the overall durability of the garment assembly. They indicated that repairing of seams in garments is very limited in the event of seam failure. Most consumers discard their garment due to seam failure because of the trouble of stitching it back. For proper appearance of garments, seams should not contain any defects such as skipped stitches, unbalanced stitches, seam grin, uneven density puckers and should be strong (Choudhary & Goel, 2013).

2.10.1 Seam Performance Testing

Seam quality may be examined from two main aspects which are functional and aesthetic performance (Sarhan, 2013). According to Germanova–Krasteva and Petrov (2007), the appearance of a seam forms the aesthetical properties of the sewing product. The functional properties refer to the strength, efficiency, elongation, bending stiffness, abrasion resistance and resistance of the seam under conditions of mechanical stress for a reasonable period of time (Sarhan, 2013). Bharani and Gowda (2012) noted that good quality seam must have flexibility and strength with no seaming defects such as puckered and skipped stitches. Choudhary and Goel (2013) stated that apparel consumers pay attention to appearance, comfort and wearability of fabrics and evaluate seam quality based on seam appearance and its strength after wear and care procedures of the apparel product. On the other hand, ASTM D6193 (2009) asserted that the end use of an apparel product controls the relative importance of the features such as strength, security and appearance required in a properly sewn seam. Seams must not pull apart under the stresses of service, cockle or tight, but

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must be extensible as the fabric or as needed by the garment (Balu, Gowri & Tharani, 2009; Bharani & Gowda, 2012). This shows that seams are expected to hold garment pieces in place for the life of the garment.

Researchers usually employ various standard methods to evaluate seam performance. Testing of seams is carried out using structured methods so that the test result can be compared (Mehta & Bhardwaj, 1998). Examples of standards used for testing seams include EN ISO 13935-1:1999 method for seam strength (strip method) and EN ISO 13935-2:1999 method for seam strength (grab method) (Olsen, 2013). As time goes by test methods are modified to meet current trends of fabric properties or to produce more reliable results (Olsen, 2013). Mirafi (2001) (as cited in Chowdhary & Poynor, 2006) tested efficiency of superimposed seams using ASTM D4632 for grab method and ASTM D4884 for wide-width method. Whereas Chowdhary and Poynor (2006) employed a modified grab test (ASTM D1683, 1994) for seam strength testing, Germanova–Krasteva and Petrov (2007) employed EN ISO 13935-1 for testing seam strength and 2 for seam's elongation. Gribaa, Amar & Dogui (2006) used ISO 13935-1 (strip method) and French norm NF G07119 (strip test method). Mukhopdhyay, Sikka & Karmaker (2004) worked with ASTM standard (D1683-90a) for testing seam tensile properties whereas Jonaitiene and Stanys (2005) used EN ISO 13950:1999 in carrying out tensile tests of seams. Choudhary and Geol (2013), Sarhan (2013), Nassif (2013) and Akter and Khan (2015) employed ASTM D1683 for evaluating seam tensile properties (strength and elongation). In addition, Mukhopadhyay, Chatterjee and Ahuja (2014) used ASTM D1683/D1683M – 11a for seam tensile properties.

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2.10.2 Performance Properties used to Determine Seam Quality

The performance characteristics of a sewn seam that are tested include; strength, elasticity, slippage, puckering, yarn severance and appearance (ASTM D6193, 2009; Barbulov-Popov, Cirkovic & Stepanovic, 2012; Bharani & Gowda, 2012; Cheng& Poon, 2002; Mukhopadhyay, et al., 2014). In addition, Abdelkarim and Seif (2001) noted the interaction of seam strength and elongation as seam quality properties. Chowdhary and Poynor (2006) also examined the interaction of seam efficiency, strength and elongation as properties contributing to seam quality in garments. The seam performance characteristics are however influenced by factors such as seam type, stitch density, sewing thread, sewing needles and fabric type and weight (American & Efird Inc., 2010; Barbulov-Popov, et al., 2012; Bharani & Gowda, 2012; Mukhopadhyay et al., 2004). It was further indicated that any one of these factors can adversely affect the performance of a sewn product depending on the end-use. The performance properties of seams discussed are:

A. Seam Strength

Seam strength is the amount of force required to break a seam (Nassif, 2013; Pizzuto, 2012). Goyal (2006) referred to seam strength as the strength required when a seam finally ruptures or when the fabric breaks. Kadolph (2007) stated that the greater the force needed to rupture the seam, the greater its strength. According to Bharani and Gowda (2012) and Mehta & Bhardwaj (1998) every seam has two components which are the fabric and the sewing thread. Seam strength must result from the breakage of either fabric or thread or both simultaneously. Research has revealed that the force required to break the seam is usually less than that required to break the un-sewn fabric (Bharani & Gowda, 2012). Barbulov-Popov, et al., (2012) and Mehta and

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Bhardwaj (1998) asserted that seam strength should correspond to material strength in order to obtain products which will be able to endure all the forces the product will be subjected to during use and care.

AMANN Inc. (2009) pointed out that if a seam's breaking strength is insufficient, the seam would tear during later use. The seam's breaking strength is determined by sewing parameters such as the fabric, sewing thread, stitch types, thread strength, stitches per inch, thread tension and seam type(AMANN Inc., 2009;Goyal, 2006; Mehta & Bhardwaj, 1998). It was noted by Mehta and Bhardwaj (1998) that generally stronger sewing threads will give stronger seams, chain stitch seam will produce stronger seams than lock stitch seams and higher number of stitches per inch will give higher seam strength. AMANN Inc. (2009) indicated that increasing the stitch density by only one stitch per centimeter, for example, leads to a 25-30% increase of seam breaking strength. It must however be stated that the type of thread and other parameters that will contribute to better seam strength can only be established through testing. Measurement of seam strength is a part of quality control procedure which is essential for garments (Doshi, 2006).When engineering seams, it is recommended that a tensile test on the fabric is done to determine its strength since an individual or manufacturer is not supposed to specify seam strength requirements that are stronger than the fabric itself (American & Efird Inc., 2009).

Various studies have been done to determine seam strength characteristics of certain fabrics with some of the factors that contribute to seam strength. Barbulov-Popov, et al. (2012) noted that stitch density and sewing thread type have great influence on seam strength and their inconsistency may lead to great differences in seam

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behaviour. American and Efird Inc. (2010) observed increase in seam strength as stitch density increased. Danquah (2010) showed that differences existed between sewing thread types with regard to seam strength and seam strength increased as stitch density increased. In a study on the investigation of the effect of sewing machine parameters on seam quality, Nassif (2013) established increase in seam strength with increase in stitch density and decrease in seam strength as needle size increased. For stitch density, Nassif (2013) noted 17% increase in seam strength with increase in stitch density. Contrary to the finding of American and Efird Inc. (2010) and Nassif (2013), Wang, Chan and Hu (n.d) observed changing patterns when stitch density was increased. Wang et al. (n.d) noted in their study on the influence of stitch density to stitches properties of knitted products that when stitch density was increased, the tensile strength at break of 301 lock stitch seam reduced. Mukhopadhyay (2008) noted increase in seam strength with increase in linear density of sewing thread. Mukhopadhyay et al. (2004) observed in their study on the impact of laundering on the seam tensile properties of suiting fabric that, seam strength and efficiency of the fabric stitched with coarser yarn was higher than the fabric stitched with finer yarn. Sarhan (2013) on the other hand, detected increase in seam strength and elongation with increase in sewing thread size from 18 to 24tex and decrease with increase in sewing thread size up to 30tex. Akter and Khan (2015) found differences in seam strength between four thread types they selected for their study with polyester filament core thread showing better seam strength and efficiency with all stitch types employed for their study.

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B. Seam Elongation

Seam elongation evaluates the elasticity and flexibility of a seam and is defined as the ratio of the extended length after loading to the original length of the seam (Sarhan, 2013). Elongation according to ISO 13934-1: (2013) is the ratio of the extension of a test specimen to its initial length, expressed as a percentage. It is the extension of the seam at break. ASTM D6193 (2009), Barbulov-Popov, et al., (2012) and Mehta and Bhardwaj (1998) indicated that the elasticity (elongation) of a sewn seam should be slightly greater than that of the material which it joins. This will enable the material to support its share of the forces encountered for the intended end use of the garment. The elasticity of a sewn seam, ASTM D6193 (2009), Barbulov-Popov, et al., (2012) and Mehta and Bhardwaj (1998) stated, depends upon factors such as fabric type and strength, seam type, stitch type, thread elasticity and stitch density. In a study on the influence of sewing needle usage time on seam quality, Abdelkarim and Seif (2001) revealed that the long period of time of using the needle increased seam elongation. Needle size and sewing thread tension were established to have negative effect on seam elongation by Nassif (2013).

Kadolph and Langford (2002) tested elongation for both fabric and seams. They noted 12% fabric elongation for warp and 16% for filling yarns, with various seams ranging from 15% to 20% for warp and 17% to 22% for the filling direction. Evidently, the elongation for seams was higher than the fabric elongation. The finding of Kadolph and Langford (2002) is in concord with the finding of Chowdhary and Poynor (2006). Chowdhary and Poynor (2006) established in their study on impact of stitch density on seam strength, seam elongation, and efficiency that the seams had significantly higher elongation than the fabric in both warp and weft directions for all stitch

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densities. They also observed differences between seam elongation and three stitch densities in both warp and filling directions of the fabric they used for their study. Nassif (2013) also found approximately 14.4% increase in seam elongation as stitch density increased. In addition, a slight increase in seam elongation as needle size increased from size 12 to 14 was observed. He noted 3.8% reduction in seam elongation as needle size increased from 12 to 16.

C. Seam Efficiency

Seam efficiency measures the durability of the seam line (Nassif, 2013; Sarhan, 2013). Seam efficiency is viewed as a function of compatibility between the fashion fabric, sewing thread, yarn size, seam type, and stitch density and is a percentage representation of the ratio of the seam strength and the fabric strength (ASTM D6193, 2009; Chowdhary & Poynor, 2006; Nassif, 2013; Sarhan, 2013). Chowdhary and Poynor (2006) pointed out that, for the purposes of interpretation, if the percentage efficiency is more than 100%, the seam is stronger than the fabric. Where it is less than 100%, the fabric is stronger than the seam, but seam efficiency of 100% is required for a perfect seam. Mehta and Bhardwaj (1998) added that when woven fabrics are seamed, the absolute seam strength is not, in the majority of cases, of paramount importance, provided it is reasonably high. They concluded that a seam efficiency of about 60-70% indicates the seam will be commercially acceptable. Nassif (2013) indicated that generally seam efficiency ranges between 85% and 90% and can be achieved through appropriate selection of factors such as seam type, sewing thread type, needles and stitch density.

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Chowdhary and Poynor (2006) observed differing seam efficiency values for three stitch densities. It was highest for 10 – 12 stitches per inch for both warp (61.29%) and filling direction (57.9%) and lowest for the 6 – 8 stitches per inch in the warp (46.39%) and in the weft (40.43%). They therefore, suggested that an attempt should be made to test each stitch length with a variety of thread types, yarn sizes, and yarn types used for both sewing thread as well as test fabric(s). Nassif (2013) observed a reduction in seam efficiency with increase in needle size. He also noted an increase in seam efficiency with increase in stitch density. He detected 16% increase in seam efficiency as stitch density increased. Sarhan (2013) proved the effect of sewing thread linear density. He observed that as the sewing thread linear density and stitch density increases seam efficiency followed same. Chowdhary (2002) employed seams from ready-to-wear garments and noted that seam efficiency of SS516 for the warp direction was 100% for stone washed jeans, 91.94% for the antiqued jeans and 82.58% for sandblasted jeans. Chowdhary (2002) suggested extension of the work on performance characteristics of textiles for other apparel items, weaves and fabrics. Chowdhary and Poynor (2006) reported that some technical information were found on seam efficiency for installing geotextiles for industrial purposes and the seam efficiency in that report ranged from 40% to 90%. Information from Amaco Fabrics and Fibers Company indicated that, for most test fabrics, seam efficiency ranged between 60% and 90% for single stitched seams and 70% to 85% for the double rows of stitching (Chowdhary & Poynor, 2006).

Chowdhary and Poynor (2006) stated that Mirafi's Report noted that typical seam efficiencies ranged between 40% and 60 %. They revealed that a scholar on Geotextile Sewing Techniques noted that seam efficiency was 50% to 70% for

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polypropylene fabrics and 40% to 50% for woven polyester fabrics. For sewing light weight materials, they used nylon, polypropylene, and polyester threads. However, for medium–weight fabrics, polyester thread was used. Seam stitch efficiency was higher for polypropylene threads (50% to70%) than the polyester threads (40 % to 50%). The discussion that follows covers some of the factors that influence the performance properties of seams.

Seams Types of Apparel Products

On the basis of standardisation there are groupings for seams. Keiser and Garner (2012) revealed that ASTM International standard D6193 -11 outlines six classes of seams and ISO 4816 mentioned just four. The classes as outlined by Keiser and Garner (2012) and Glock and Kunz (2005) are superimposed seams (SS), lapped seams (LS), bound seams (BS), flat seams (FS) with the other two ASTM international seam classes being ornamental stitching (OS) and edge finishes (EF) which are classified as stitching classes in ISO standard (Keiser & Garner, 2012). ASTM International D6193 (2009) indicated that each class of seam is subdivided into types. Seam type, in sewn fabrics, is explained by ASTM D6193 (2009) as an alphanumeric designation relating to the essential characteristics of fabric positioning and rows of stitching in a specified sewn fabric seam. The seam types are designated by symbols consisting of three parts. The first part denotes the class of seam and is represented by two or more upper case letters; for example, SS. The second part denotes the type of the class of the seam and is depicted by one or more lowercase letters, for example, a. The third part signifies the number of rows of stitches and is indicated by one or more Arabic numerals preceded by a dash; for example -1. For example, the symbol for a simple super-imposed seam type with one row of stitches is

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SSa-1. Other examples are EFn-4, LSd-1 and EFaf-2. It was stated that as the lower case letter increases the more complex and stronger the seam becomes (ASTM D6193, 2009).

Certain seam types are more appropriate for some apparel products and fabrics than others (Glock & Kunz, 2005; Stamper et al., 1991). Seam type influence seam strength and can affect the performance of a sewn product depending on the end-use (American & Efird Inc., 2009).In a study on the effects of different fabric types and seam designs on the seams efficiency, LaPare (2006) revealed that in terms of seam efficiency, the wool fabric was slightly higher for the SSn seam than the SSa seam. In addition, he found that seam SSn appeared to produce a stronger joint in the wool fabrics. Mukhopadhyay et al. (2014) also found that the breaking strength and elongation for lap felled seam were greater than plain seam.

Sewing Threads for Stitching Apparel Products

Garments are usually constructed with the use of stitches which require sewing threads. Careful sewing thread selection is essential to prevent damage to seams requiring immediate repair which shortens the life of a garment (Gurarda, 2008). American and Efird Inc. (2010) indicated that thread shares 50% of seam responsibility although it accounts for a small percentage of the cost of a finished product. Stamper et al. (1991) asserted that one very essential aspect of thread/fabric coordination is that the thread should be weaker than the fabric it joins without indicating the extent of weakness. Broken stitches can be repaired but if the thread is stronger than the fabric it joins, undue stress can result in the fabric splitting at the seam lines. This kind of damage will not be easy to repair and still maintain the

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garments' original size and aesthetic properties (Stamper et al., 1991).American and Efird Inc. (2004) reiterated that generally, the repair costs incurred by using inferior thread will be greater than the cost difference of using the right thread at the beginning.

There is wide range of sewing threads available on the market (Jonaitiene & Stanys, 2005). This has occurred due to the following reasons a) development of new fibres, b) development and improvement of new thread manufacturing processes and c) continuous demand from the industry to get various sewing threads designed for sewing a wide assortment of articles (Jonaitiene & Stanys, 2005). They emphasized that about 70-80 percent of the sewing threads manufactured are used by the clothing industry. Threads commonly used in the manufacture of garments are those of cotton and polyester (Kalaoglu, 2001). Babu, Koushik and Ramachandaran (2009) indicated that polyester threads are taking over the sewing thread market due to their high strength, low degree of shrinkage on washing and good wearing properties compared to cotton threads. One of the properties of sewing threads that influence seam performance is elongation (Gurarda, 2008). According to Doshi (2006), the elongation of sewing threads should be equal to that of the fabric used, consequently different fabrics require threads of different elasticity (e. g. threads used for knitted, synthetic or woven fabrics are different). Cotton thread was mentioned to typically have extensions at break of 6-8 percent with synthetic threads having 15-20 percent and higher for certain specialty thread for specific end-uses (Doshi, 2006).

Other properties of sewing threads that contribute to seam performance include fibre content, its construction (structure), twist, ply, size and finishing (AMANN Inc.,

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2009; American & Efird Inc., 2009;Bharani & Gowda, 2012; Doshi, 2006; Glock & Kunz, 2005). Some fibres produce stronger threads than others and have greater loop strength contributing to greater seam strength (American & Efird Inc., 2009). Example 100% polyester thread provides greater seam strength than a 100% cotton thread of the same size. Doshi (2006) added that fabrics type to be sewed determines the fibre type of thread to be selected (e. g. silk fabrics require silk threads). With regard to thread construction, Doshi (2006) reported that core threads made with continuous filament polyester core; generally provide higher seam strength than spun and textured threads. In a study on performance of polyester/cotton sewing threads on seam strength, Babu et al. (2009) observed that 100% polyester thread showed high seam strength and efficiency compared to polyester core/cotton wrap thread. In addition, the size of sewing thread is also crucial as improper choice directly affects seam quality in garments (Bharani & Gowda, 2012; Choudhary & Goel, 2013; Sarhan, 2013).

Sarhan (2013) observed that finer sewing threads were suitable for light weight fabrics and coarser ones for heavy weight fabrics. Similarly, Sunderesan, Salhotra and Hari (1998) found that sewing thread size and ply are largely the most influencing factors with regard to seam puckering and strength. Farhana, Syduzzaman and Yeasmin (2015) noted that seam strength for both superimposed and lapped seams were better for thread with linear density of 60tex than 105tex. Gribaa et al. (2006) established that thicker threads give better seam strength; however such a thread requires the use of thicker needle which may damage the fabric. American and Efird Inc. (2009) reported that, given a specific fibre type and thread construction, the larger the thread size, the greater the seam strength. Mukhopadhyay et al. (2004) found that

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initial and secant moduli of fabric sewn with finer yarn were lower as compared to the fabric sewn with coarser yarn. Their explanation was that the coarser yarn possesses higher moduli than finer yarn. They also detected that seam strength and elongation increased with yarn thickness, and work of rupture of seam was higher for coarser yarn than that of finer yarn.

Mukhopadhyay (2008) also established greater improvement in seam strength, seam strain at break and work up to fracture with a change in thread linear density in the case of chain stitched seam. Likewise, Choudhary and Goel (2013) observed that seam puckering and strength increased with increase in sewing thread linear density. Seam appearance, which is one of the performance characteristics of seams, is also dependent upon the proper relationship between the size and type of thread, stitch density and the texture and weight of the fabric (ASTM D6193, 2009).

Stitch Types and Stitch Densities for Stitching Apparel Products

Stitches hold garment pieces together as a result have critical impact on the overall quality of the finished product (Keiser & Garner, 2012). Gurarda (2008) asserted that the basic foundation of sewing is the stitch. A stitch in sewing is defined by ASTM D6193 (2009) and Keiser and Garner (2012) as the configurations of interlacing of sewing thread executed in specific repeated units. A series of recurring stitches of one configuration are known as stitch type (Gurarda, 2008). In both casual and formal garments, stitching help achieve certain objectives, which according to Abernathy, Dunlop, Hammond and Weil (1999), include; joining individual pattern pieces, leaving no raw edges of fabric unravel and for decoration. Keiser and Garner (2012) reported two standards that provide different classes of stitch types. The standards are

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ASTM D6193 and ISO 4910.Commercial stitches indicated in the ASTM International standard are divided into six, but ISO has eight classes depending on the complexity, configuration and the type of machine required for stitching (Keiser & Garner 2012). It was further stated that each of the stitch classes has distinct benefits and drawbacks; consequently, stitch selection for garment construction depends on their proposed end-use.

Keiser and Garner (2012) and Glock and Kunz (2005) reported the following stitch classes: class 100 representing single-thread chain stitches, 200 representing hand stitches, 300 for lock stitches, 400 for multi thread chain stitches, 500 for overedge stitches and 600 representing cover stitches. Class 300, 400, 500 and 600 are the extensively used stitch types for garment construction (Gurarda, 2008). Chowdhary and Poynor (2006) emphasized that the choice of stitches is vital in producing good quality garments. They reiterated that improper selection of stitch types and stitches per inch can make the most excellent fabric perform inefficiently and the opposite holds when the right choices are made in time.

The elongation and the strength of a seam, for example, can be affected due to differences in stitch types used for a garment assembly (Gribaa et al., 2006). Gribaa et al. (2006) found that the extent of seam deformation increased as the stitch moved from lock stitch to double chain stitch. Gribaa et al. (2006) explained that this result occurred due to the characteristics of the two stitches. The lock stitch piles up better seams whereas; double chain stitch gives more elasticity due to its way of formation. In a study on the effect of lock stitch and chain stitch at the seat seam of a pair of trouser for military armed forces, Mukhopadhyay (2008) observed that performance

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of chain stitched seam was much better compared with lock stitched seam as regards force at break, strain at break and work of rapture. The outcome of Mukhopadhyay (2008) study confirms American and Efird Inc. (2009) assertion that generally, the more thread consumed in a stitch, the greater the seam strength, when they compared 301 lock stitch seams to 401 chain stitch seams. They explained that threads used in 301 lock stitch seams are more susceptible to sharing each other than 401 chain stitch.

Stitch length is specified as the number of stitches per inch (spi) or stitch density and is indicative of seam quality, speed and cost of production (Glock & Kunz, 2005). Glock and Kunz (2005) stated that a seam sewn with 8 spi could be sewn three times faster than one requiring 22 spi if maximum speed is maintained. In addition, the more spi, the more thread needed to sew the seam, as a result cost of production is increased. The selection of most appropriate stitch density depends on the fabric to be sewn and the needed seam properties (Gribaa, et al. 2006). According to Glock and Kunz (2005) and Nassif (2013), high spi means short stitches; low spi means long stitches. Short stitches they noted produce more stable and less obviously line of stitches which produces greater seam strength. Long stitches on the other hand, are usually less durable and considered lower quality as they are more subject to abrasion, snagging and grin-through (Glock & Kunz, 2005). An example is that men's dress shirt with 22 spi is considered high quality compared to one with 8 spi. To Glock and Kunz (2005) and American &Efird Inc. (2010) generally the greater the spi the greater the holding power and seam strength. On the other hand, high spi has the potential to increase seam pucker and weaken the fabric (this merely happens on fabrics vulnerable to excessive needle penetrations) (American & Efird Inc., 2010; Gurarda, 2008; Mehta & Bhardwaj, 1998), consequently, fabric attributes must be weighed in

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deciding the best spi suitable (Glock & Kunz, 2005). For American and Efird Inc. (2010) individuals writing garment specifications should constantly state the accurate number of stitches per inch (SPI) necessary for the sewn products. They explained that the number of stitches per inch can greatly affect; the seams strength, stitch appearance and elasticity especially on stretch fabrics.

Wang, Chan and Hu (n.d) found that the patterns of influence of stitch density on various stitches differ. They noted for example, that with increase in stitch density tensile strength of 301 lock stitch seam reduced while the tensile strength of 504 three thread over lock stitch seam increased gradually. In addition, it was established that for 301 lock stitch seam, increased stitch density, increased the rate of extension at break for stitched samples at cross direction but decreased the elongation of those stitched at warp direction, whereas for 504 seams when the stitch density was increased, the breaking elongation for both warp and weft samples of the fabric increased. Chowdhary and Poynor (2006) detected some patterns that confirmed the norm and the position of American and Efird Inc. (2010) that generally the more stitches per inch, the greater the seam strength. Chowdhary and Poynor (2006) found that differences for seam strength were significant for three stitch densities in both warp and filling directions with strength increasing as stitch density increased. It was revealed that seams with 14-16 SPI had the highest elongation in both directions. They also found that the fabric they employed in their study was significantly stronger than the seams in both warp and filling directions for all three stitch densities used for the study.

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Fabrics for Making Garments

Fabric type and weight can influence seam performance depending on the fibre content (100% cotton, cotton/polyester blend, nylon), fabric construction (woven or knit), type of weaves used (plain, twill, jersey, tricot); fill count, yarn type and size, pattern placement, seam direction and propensity of the yarns in the seam to shift or pull out of the seam (American & Efird Inc. 2009). Choudhary and Goel (2013) and Bharani and Gowda (2012) also indicated that fabric properties which affect seam quality are cover factor, weight, thickness, strength, shrinkage, functional finishes, extensibility, bending rigidity and shear rigidity. For instance, it has been established that fabric bending property is an essential factor affecting seam puckering (Gribaa et al., 2006).

Cheng and Poon (2002) found that fabric weave, weight, thickness and direction (warp, weft, bias) affect seam strength. They noted in their study on the seam properties of some selected woven fabrics that plain weave fabric had higher seam strength and greater seam pucker compared to twill weave. Again the heavier and thicker the fabric, the higher the seam strength and lesser the seam pucker. Bharani and Gowda (2012) also found that the plain weave fabric they used in their study on 'the characterisation of seam strength and seam slippage of PC blend fabric with plain woven structure had higher seam performance than other weave types. Contrary to these findings, Mukhopadhay et al. (2014) observed that the twill fabric they used for their study showed higher breaking strength and elongation than the plain fabric. Studying the influence of sewing parameters on the tensile behaviour of textile assembly, Gribaa et al. (2006)realized that results in warp direction proved some differences with weft direction in seam performance and stated that, the fabric

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construction affects the behaviour of sewn fabrics. They noted further that there were certain differences which confirmed those influences of fabric construction where differences between yarns (twist, size, yarn fibre, density) affected the friction behaviour of seams (strength and slippage). Babu, Koushik and Ramachandaran (2009) observed that seam strength and efficiency depend on direction of the seam with regard to the fabric. They uncovered that weft-way seams were stronger than the warp-way seams, weft-way seam strength increased with increase in stitches per inch, but the warp-way seams showed just a slight variation at higher stitch density.

In a study on the interaction between sewing thread size and stitch density and its effects on seam quality of wool fabrics, Sarhan (2013) found that increase in thread size and stitch density led to increase in seam strength and elongation of heavy weight wool fabrics. This indicates the need to investigate seam performance of various fabrics by varying sewing parameters to establish which parameters will be best suited for each type of fabric. Studying the impact of laundering on seam tensile properties of suiting fabrics, Mukhopadhyay et al. (2004) uncovered that coarser yarn have greater impact on seam properties of polyester/cotton fabric than cotton fabric. Both initial and secant moduli were reduced after laundering with the reduction being greater in polyester-cotton blended fabric. The explanation provided by Mukhopadhyay et al. (2004) for the observation was that the fabric composition had greater influence on the initial and secant moduli of the seam.

2.11 Effects of Laundering on Garments

In the lifetime of a garment, both cloth and seams undergo repeated laundering, which may result in change in quality and performance of the sewn product (Mukhopadhay,

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et al., 2004). Germanova-Krasteva and Petrov (2007) stated that the underwear and outer garments are washed and overcoats dry-cleaned. Moris and Prata (1977) indicated that as much as half of garment degradation happens in laundering. They emphasized that, for instance, abrasion may occur both in washing and in drying, and studies (e.g. Fainu & Adams, 1998; Fianu, Sallah & Ayertey, 2005; Lee & Kim, 2004; Mikučionienė, 2004; Herath & Bok, 2009) have shown that water quality, detergent type, and drying conditions are important variables affecting the amount of damage. Textile laundering is the largely applied care procedure employed for the exploitation process of clothing (Koženiauskienė & Daukantienė, 2013). For instance, Germanova-Krasteva and Petrov (2007) and Mukhopadhyay et al. (2004) stated that one of the factors used to assess the properties of seams in apparels is the conditions of washing and dry cleaning.

As school uniforms go through their cycle of use, they are exposed to conditions in wear and care such as washing, which influences their overall performance. Fabrics and seams selected to be used for uniform production therefore have to be evaluated by subjecting them to conditions such as washing to determine their suitability. Researchers in the area of clothing and textiles have taken steps to identify the effects of some conditions, such as sunlight and washing, and have given their recommendations as to the fabrics use and care. Fainu and Adams (1998) for example, noted that washing and sunlight caused the colour of Real Wax, Real Java, and Batik fabrics produced in Ghana, to fade; and suggested that they are dried in the shade. Fianu, Sallah and Ayertey (2005) also found that sunlight caused loss of strength in Real Wax printed fabrics from Ghana Tex Styles Ghana Limited with laundered specimens losing more strength.

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In a study on the effect of laundering on the dimensional stability and distortion of knitted fabrics, Anand et al. (2002) discovered changes in the dimensions of the fabrics studied due to laundering with the changes occurring after laundering due to the agitation during tumble drying. The agitation was observed to have caused 34% of the changes during laundering, followed by the spin cycle during washing, which caused 24% of the dimensional changes and distortion. In addition, the work by Toshikj and Mangovska (2011) on the effect of laundering of cotton knitted fabrics with different detergents on dimensional stability and colourfastness, demonstrated that structural characteristics and shrinkage increased linearly with repeated laundering regardless of the type of the detergent and grade of cotton. They also found that dyed knitted fabrics had excellent colour fastness to washing. Orzada, Moore, Collier, and Chen (2009) noticed that increased laundry treatments increased overall drape values and reduced each of shear and bending parameters resulting in more pliable, drapable fabrics. Senthilkumar and Anbumani (2012) observed that the dynamic work recovery (DWR) of cotton/spandex fabric increased with increase in washing cycles from first to the tenth wash and decreased at 20th wash.

Mukhopadhyay et al. (2004) observed interaction of sewing parameters and laundry on seams performance. They found that the effect of stitch density, count of sewing threads, fabric composition and laundering on seam tensile properties of suiting fabric were very significant. Both initial and secant moduli decrease after laundering; with the decrease being greater in polyester-cotton blended fabric. Reduction in seam strength and seam efficiency as a result of laundering was greater for coarser sewing threads. However, seam strain at fracture increased slightly, but work of rupture reduced after laundering.

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Shawky (2013) established that laundering was a major factor that affected the performance of seams in a study on effect of home laundering on sewing performance of cotton fabrics. Laundering had significant effect on seam efficiency and elongation as it decreased seam efficiency. Mukhopadhyay (2008) also found that force at small strain and force at break increased on laundering, with the change being more in the case of lock stitched fabric stitched with coarser sewing thread. Nonetheless, strain at break decreased a little on laundering in the case of both lock and chain stitches. Babu, Koushik and Ramachandaran (2009) noticed that in the case of all the threads they used for their study on 'performance of polyester/cotton sewing threads on seam strength' the warp-way seams showed distinct increase in strength with increase in the number of washes. On the other hand, the weft – way seams showed marginal increase with increase in the number of washes. Again seam efficiency reduced with increase in the number of washes and fabric strength increased with increase in number of washes, but no proportional increase was observed in seam strength. They also noted that seam slippage increased as wash cycle increased.

2.12 Summary of Review

Summing up, the literature review provide evidence that to obtain good quality garments there is the need for appropriate selection of fabrics and sewing parameters (e. g. stitch density, thread). Continuing satisfactory performance of garments such as school uniforms throughout their use life is of great concern to consumers as consumers demand and expects value for their monies spent on products. In order to determine whether fabrics and seams used for specific garments can withstand their end-use requirements, testing and inspection procedures are employed. In the textile and clothing industry, testing and inspection has become an important segment

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because through that faults on machinery and materials can easily be detected and corrected or improved upon to achieve product quality and compliance to international, regional or retailers specific standards. However, although studies on fabrics and seam performance of other fabrics have been carried out, none of the reviewed works reported on fabric and seam performance of uniform fabrics used by Ghanaian Public Basic school pupils. For instance, Masteikaité et al. (2013) evaluated seven suiting fabrics to determine their suitability for school uniforms. They selected the fabrics from Kazakhstan and Lithuanian factories. Unal et al. (2011) studied four different trouser fabrics used for primary school uniforms in Turkey. Özdil et al. (2014) examined properties of knitted fabrics used by primary school children in Turkey. Adetuyi and Akinbola (2009) assessed the characteristics of uniform fabrics used by pre and post primary schools in Akure metropolis, Nigeria. Chowdhary (2002) analysed seams in ready to wear apparel, LaPere (2006) investigated seams in wool, cotton and silk fabrics, Chowdhary and Poynor (2006) worked on seams in 100% cotton muslin fabric, Mukhopadhyay et al. (2004) and Choudhary and Goel (2013)studied seams in suiting fabrics, Germanova–Krasteva and Petrov (2007) assessed seams in light fabrics and Gurarda (2008) evaluated Pet/Nylon-elastane woven fabrics. In addition, Sarhan (2013) used twill wool fabrics for seam performance evaluation.

Furthermore, general focus of research on school uniforms has been on textile testing with much emphasis on fabric performance properties. In other instances school uniform garments are analysed based on visual inspection of their quality and how consumers are satisfied with the uniform usage leaving the mechanical aspects, which involve seams performance properties testing. Consequently, giving the importance of

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fabric and seam performance in the achievement of good quality garments for their end-use, this research seeks to fill the gap in research on school uniforms used by Ghanaian public basic school pupils. Thus this study investigated the suitability of fabrics currently used for the production of Ghanaian public basic school uniforms and determined sewing thread brand and stitch densities that would help achieve overall quality in a suitable fabric for school uniform production.

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CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The chapter describes the design employed for the study, sample and sampling procedures, instruments for the data collection, data collection procedures as well as the methods used in the analysis of the data collected. The study was in two phases. The first phase assessed the suitability of fabrics used in the production of Ghanaian public basic school uniforms based on the fabrics performance properties. Based on the fabric performance evaluation results, one of the fabrics that met the standard requirements of the Ghana Standards Authority for school uniforms was selected for the second phase. The second phase involved seam performance analysis on the selected fabric by varying sewing threads, stitch densities and wash cycles.

3.2 Research Design

The experimental research design was employed for the two phases of the study with the use of laboratory testing for the analysis of the performance properties of fabrics and seams. Kadolph (2007) stated that laboratory tests are well organised, systematic and carefully planned, therefore meet the criteria for research studies to be credible and accepted by other researchers. The primary reasons for laboratory testing as described by Glock and Kunz (2005) is to determine levels of performance needed, establish quality standards and determine scientifically whether products conform to standards, which meets the purpose of this research. With regard to phase one, the independent variable was the number of times of washing. The dependent variables were colourfastness, weight, strength, elongation and dimensional stability of the

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fabrics selected for the study. Ary, Jacobs and Razavieh (2002) noted that an experiment is a scientific investigation in which the researcher manipulates one or more independent variables and observes the effect of the independent variable(s) on the dependent variables.

In the second phase of the study, a 2×3×3 factorial design was employed that included two brands of sewing threads, three ranges of stitch densities and three wash cycles. According to Ary, Jacobs and Razavieh (2002), a factorial design is an experimental design that investigates two or more independent variables at the same time. They stated further that in a factorial design, the researcher manipulates two or more variables simultaneously in order to study the independent effect of each variable on the dependent variables as well as the effects caused by the interactions among the several variables. The three independent variables in the second phase of the study were sewing thread brand, stitch density, and wash cycle. They were manipulated by combining them to evaluate their effects singly and in combination with the dependent variables seam strength, efficiency, and elongation.

The study adopted the quantitative approach because there were predetermined standards that were used to experimentally assess the quality of fabrics used for the production of uniforms. The quantitative approach helped to collect data from a representative sample which allowed for generalisation and replication (Creswell, 2009). It was the researcher's believe that the nature of the variables involved in this study were best to be examined by the use of the experimental design as explained.

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3.3 Study Location

The data collection procedures took place at two locations. The locations were:

1. The laboratory of the Ghana Standards Authority (GSA) textile testing department. The GSA's textile testing laboratory was used for the study as the Authority is a government agency involved in the development of standards and certification of products including textiles. The investigations carried out on all the parameters took place at the GSA's textile testing laboratory except for strength and elongation.
2. The laboratory of the Materials Science Department of School of Engineering, University of Ghana, Legon was used to carry out the investigations on strength and elongation. This became necessary because of the need for tensile testing equipment which they owned.

3.4 Phase One of the Study: Fabric Performance Evaluation

For phase one of the study, the performance characteristics of three brands of fabrics currently used for Ghanaian public basic school uniforms were assessed based on the Ghana Standards Authority's (GSA) standards for uniform fabrics (*GS 970, 2009).* This helped to select a suitable fabric for public basic school uniforms which was used for the second phase of the study. The characteristics evaluated on the three brands of fabrics were fibre content, weave type, weight, strength, colourfastness and dimensional stability (shrinkage). These characteristics were covered in the GS 970:2009.Other fabric characteristics investigated that were not covered in the GS 970:2009, but the researcher through literature reviewed realised such characteristics are also important in determining the overall performance of uniform fabrics were: yarn count, yarn linear density, elongation and absorbency. In addition, the effect of

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the number of times of washing on the performance properties (colourfastness, weight, strength, elongation and dimensional stability) of the three brands of fabrics was also determined, since the school uniform are usually washed after wear.

3.4.1 Materials used for Phase One of the study

The materials used for the phase one of the study were:

i. Fabric Samples

Three different brands of fabrics usually used for the production of public basic school uniform were chosen for the study based on interaction with uniform manufacturers, fabrics sellers and retailors of basic school uniforms. The three different brands of fabrics studied were first labelled A, B and C without providing their specific brand names for ethical reasons. There were two types of each fabric brand labelled A1, A2, B1, B2 and C1, C2. A1, B1 and C1 were chocolate 4/saddle brown colours used for skirts, pinafore or a pair of shorts. A2, B2 and C2 were sandy brown colours used for shirts and blouses (Table 3.1). For the purpose of this study, 5.5 metres of each of the colours of fabrics from the three brands were bought from the market. Three different chocolate 4/saddle brown and 3 different sandy brown fabrics were obtained making a total of 6 different fabrics which were assessed. One brand was locally produced (brand A) and the other two were imported (brands B and C). In terms of prices, brand A was GH₵25 per yard while brand B was GH₵10 per yard and C GH₵8 indicating brand A as the most expensive. Table 3.1, page 108, shows the quantity of fabrics used for phase one of the study.

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ii. Soap used for Washing Tests

Key bar soap, produced by Uniliver, Ghana Limited, was purchased from the market and used for washing tests. Fianu, Sallah and Ayertey (2005), in a study on the effect of sunlight and drying methods on the strength of Ghanaian Real Wax printed fabrics, used key soap. They stated that key soap is one of the popular soaps used by Ghanaians for washing coloured clothes. In addition, Kwame (2012) indicated that key soap is one of the most popular soaps, least expensive and are mostly available in the Ghanaian markets. Market Express (2006) also indicated that Key Bar soap has been used by Ghanaians for many years and has become a Ghanaian tradition and not just a soap. Market Express stated further that it washes great and perfect for coloured fabrics. These statements influenced its selection for this study.

Table 3.1: Fabric brands and quantities used for phase one of the study

Fabric Samples	Colour	End-use	Quantity (Metres)
Brand A			
1	Chocolate 4/saddle brown	Pair of shorts, skirts, Pinafores	5.5
2	Sandy brown	Shirts, blouses	5.5
Brand B			
1	Chocolate 4/saddle brown	Pair of shorts, skirts, Pinafores	5.5
2	Sandy brown	Shirts, blouses	5.5
Brand C			
1	Chocolate 4/saddle brown	Pair of shorts, skirts, Pinafores	5.5
2	Sandy brown	Shirts, blouses	5.5
Total metres of fabric employed for Phase one of the study			**33**

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3.4.2 Instruments used for Phase One Data Collection

Standard testing instruments used by the Ghana Standards Authority and the Materials Science Department of the University of Ghana for evaluating the performance characteristics of textiles were employed. They were:

i. Standard Launder-Ometer (Gyrowash 315).
ii. Tensile testing machine (Mark-10 Force Gauge Model M5-500).
iii. Magnifying glass.
iv. Weighing balance (Adams equipment, B215846278).
v. Pair of scissors.
vi. Sample cutter(James H. Heal, 230/002595).
vii. Tape measure.
viii. Grey-scales.
ix. Colour assessment chamber.
x. Soxhlet extraction apparatus.
xi. Desiccator.
xii. Ventilated oven.

See Appendix B for pictures of some of the instruments used for the investigations.

3.4.3 Experimental Procedure: Phase One

With regard to this study, it must be noted that test methods by ISO adopted by GSA were used by the researcher. Before the data were collected the specimens were conditioned for 24 hours in a relaxed state at a relative humidity of 65 ± 2% and a temperature of 21°± 1°C as indicated by the ISO 139 (1973), for the specimens to be in a relaxed state and have the same temperature before testing for reliable results. Details of the distribution of the total number of specimens used for the phase one of

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the study is presented in Tables 1 and 2 (Appendix C). The labels for specimens used for easy identification are shown in Tables 3 and 4 (Appendix D).The following performance characteristics were determined:

i. Woven Fabric Yarn Count

Following ISO 7211-2:1984, three specimens each measuring 2.5cm in the warp direction and 2.5cm in the weft direction were cut from each brand of uniform fabric and labelled for easy identification (Table 3, Appendix D). A magnifying glass was used to test for yarn count where the numbers of yarns in the warp and weft directions of the specimens were counted 5 times and each recorded separately. After that an average warp and weft count was calculated for each fabric type.

ii. Weight of Fabric

Based on GS ISO 3801:1977, five specimens each with the area of 0.015m^2 were cut with the help of a sample cutter form each fabric brand and labelled (Table 4, Appendix D). Each specimen was weighed using Adams equipment weighing balance, Model No. B215846278. The average weight of the five specimens were calculated and indicated in grams per square meter.

iii. Colourfastness to Washing

Two specimens 10cm×4cm were cut from each brand of fabric and labelled (see Table 4, Appendix D for labelling details). A multi-fibre fabric of same measurement was attached to each specimen. The specimens were then washed using Standard Launder-Ometer (Gyrowash 315) and dried at room temperature after which colourfastness assessment was carried out using the ISO Grey Scale for colour change

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(Fianu & Adams, 1998; ISO 105-A02:1993, Textiles-Test for colour fastness-Part A02: Grey scale for assessing change in colour). To assess fastness to staining, the ISO grey scale for staining was used. Five readings were recorded in the visual inspection of the specimens for colour change and staining for each fabric in a well-lighted colour assessment chamber. The grey scale ratings ranged from excellent to poor with grade 5 being excellent, 4 very good, 3 good, 2 moderate and 1 poor colourfastness.

iv. Dimensional Stability (Shrinkage) to Washing

Two specimens measuring 15cm×15cm were cut from each fabric such that the yarns in both directions (warp and weft) were parallel to the edges and labelled for easy identification (see Table 4, Appendix D for labelling details). Two lines of 10cm apart and 2.5cm from the specimen edges were marked on each specimen (see Figure 3.1, page 112). The specimens were washed with Standard Launder-Ometer (Gyrowash 315) and dried at room temperature. After that, the distance between the marked lines (10cm×10cm) were re-measured from each direction (warp and weft) of the specimen with the aid of tape measure and recorded to determine if any change in the original length (10cm×10cm) occurred. Percentage dimensional change (shrinkage) was calculated with the formula provided by GS ISO 5077 (1984), which was:

$$\text{Dimensional Change} = \frac{\text{Change in Length}}{\text{Original Length}} \times 100$$

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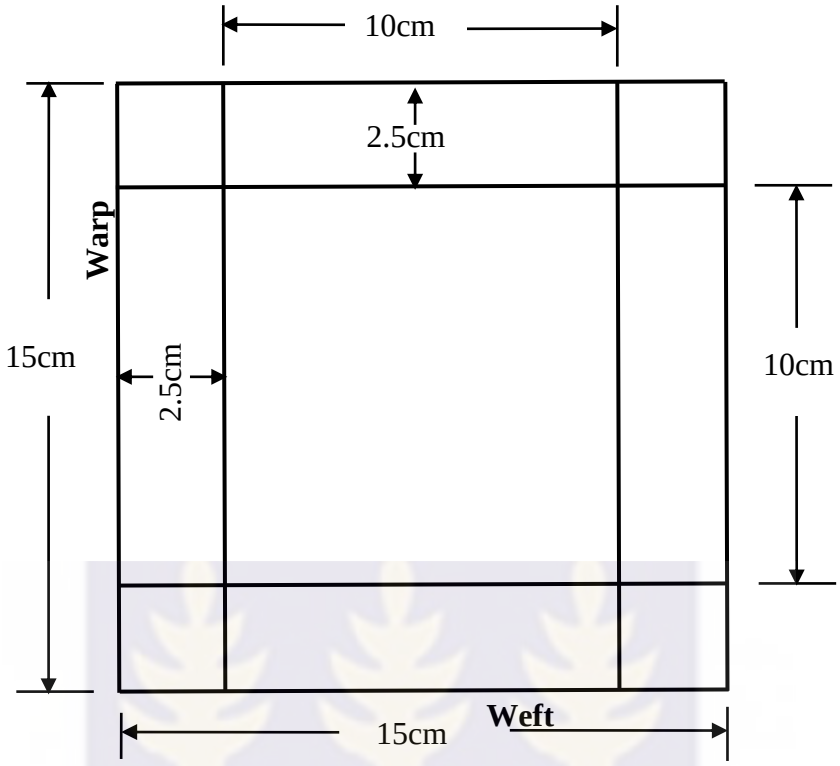


Figure 3.1. Sample specimen for dimensional stability measurement

v. Yarn Linear Density of Fabrics

Seven rectangular specimens (2 for warp, 5 for weft) measuring 50cm×2.5cm were cut from each fabric and labelled (Table 3 Appendix D). From the 7 specimens, 350 (100 for warp and 250 for weft) strands of threads were removed. The 100 strands representing warp threads were weighed together using Adams equipment weighing balance, Model No. B215846278. The 250 weft threads were also weighed in a group of 50. Linear density was calculated with the formula provided by 1SO 7211/5 (1984) as:

$$\text{Linear density in tex units} = \frac{\text{Mass of threads taken from fabric in grams}}{\text{Total length of threads in meters}} \times 100$$

where total length= mean straightened length× number of threads weighed.

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vi. Fibre Content of Fabrics

To determine the fibre contents of the fabrics, burning tests were undertaken to help establish possible blends. From the test results, it was noted that the fabrics were possible blends of cellulose and synthetic fibres. Further analysis was carried out on the fabric samples following ISO 1833-1 (2006) (quantitative chemical analysis-parts 1, 7 and 11). Based on ISO 1833-1 (2006), 2grams of specimen weight were cut from each fabric sample for pre-treatment to remove non-fibrous matter such as oils, fats, waxes and starch from the specimens. From the pre-treated specimens 1g of test specimens were cut and placed in conical flasks containing Meta Cresol solution and agitated to determine the presence of polyester fibres. The contents of the flasks were filtered, dried and the residues weighed. To determine whether the residues were cotton or viscose, the residues were placed in conical flasks containing 60% sulphuric acid. After agitation, it was noted that, the fabric brand A residue dissolved completely while that of brands B and C did not, 75% Sulphuric acid was then added to the residues of fabric brands B and C and they dissolved completely. This indicated that brand A contained viscose while brand B and C contained cotton. Their percentages were then calculated using the equation viz: Percentage Dry = 100(F – G/F), where F = original dry specimen mass in grams and G = the extracted dry residual mass in grams.

vii. Fabric Absorbency

To test for absorbency, a specimen size of 30cm×30cm was cut from each fabric sample following test method AATCC/ASTM TS-018 (procedure for absorbency of textiles by measuring the time it takes a drop of water placed on the fabric surface to be completely absorbed into the fabric). The specimens were placed over the top of a

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beaker with the centre unsupported. A drop of water was placed on the specimen 1cm from the surface of the specimen and time recorded until the specimen completely absorbed the drop of water. The specimen that absorbed with the minimum time was deemed to be very absorbent.

viii. Fabric Strength and Elongation

The ISO 13934-1 (2013) was used for testing fabric strength and elongation with the help of a tensile testing machine (Mark-10 Force Gauge Model M5-500). Forty specimens (20 from the warp and 20 from the weft, Table 1 Appendix C) each measuring 15cm×5cm was cut from each fabric and labelled (see Table 4, Appendix D for labelling details). The lengthwise direction of each specimen was frayed to obtain 15cm×3cm for testing (Figure 3.2, page 115). The gauge length of the tensile testing machine was 100mm and the rate of extension or the speed was set at 25mm/minute. Force (strength) at break and the elongation (extension) at break were recorded for each specimen in both the warp and weft directions after each wash cycle. These were done for the unwashed specimens serving as controls as well. Maximum forces at rupture were recorded in Newtons (N). Elongation was recorded in millimetres and calculated using the formula indicated in ISO 13934-1 (2013) as:

$$\text{Breaking elongation} = \frac{\text{Elongation}}{\text{Original length}} \times 100$$

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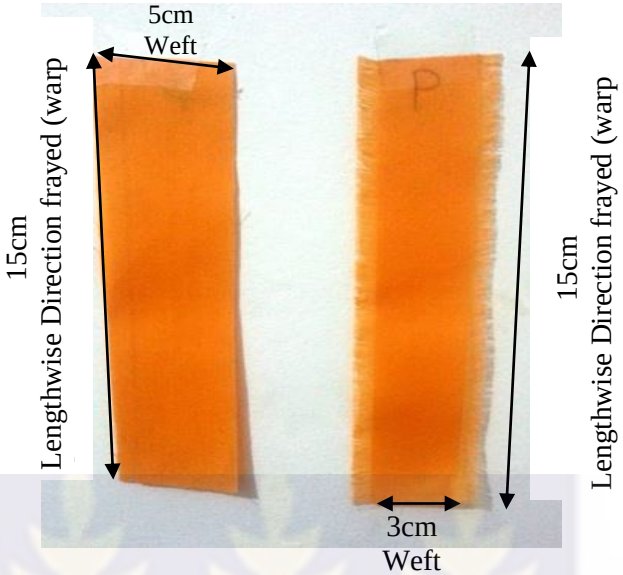


Figure 3.2: Picture of specimen used for testing tensile strength and elongation of fabric

3.4.3.1 Washing Procedures for Phase One of the Study

The procedures used by Ghana Standards Authority (GSA) Textile testing Laboratory for preparation of soap solution and washing for washing tests were followed.

3.4.3.1.1 Preparation of Soap Solution for Phase One of the Study

A stock solution of key soap was prepared for washing the specimens. Based on the weight of the specimens washed,33 grams of soap was dissolved in 6.6L of water and that was able to wash all the specimens in the three wash cycles.

3.4.3.1.2 Washing using the Launder-Ometer

The specimens to be washed were subjected to washing in the Standard Launder-Ometer (Gyrowash 315) with the solution prepared from the key soap. The washing

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was done at 60°Ctemperaturefor 30 minutes and followed by rinsing in each wash cycle.

3.4.3.1.3 Drying of Specimens

The washed specimens were dried at room temperature. The specimens after drying were not ironed, but were tested for the various parameters identified.

3.5 Phase Two: Seam Performance Evaluation

The reason for this phase of the study was to help suggest sewing thread brand(s) and stitch density(s) that would help achieve quality seams in a suitable school uniform fabric. The suggestion for the suitable school uniform fabric was similar to what Ünal, Acar and Yildirim (2015) did after evaluating performance characteristics of lining fabrics used for children dresses. They also suggested a suitable lining fabric to be used for children's dresses. Similarly, other researchers that evaluated quality of school uniform fabrics such as Adetuyi and Akinbola (2009), Chan et al. (2006) and Masteikaitė et al. (2013) made recommendations for suitable fabrics. The second phase of the study therefore examined sewing thread brands, stitch densities and the number of times of washing that would influence seam strength, efficiency and elongation of a suitable fabric for school uniforms.

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3.5.1 Materials used for Phase Two of the study

The materials employed for phase two of the study were:

i. Fabric Sample

From the results of the phase one of the study, fabric brand B was found to be the best for school uniforms in the Ghanaian climate. Based on that, 11 metres of fabric B2 (sandy brown colour) was used for seam analysis. However, the procedures that were employed for this part of the study could also be used to test fabric B1(chocolate 4/saddle brown colour).

ii. Sewing Threads for Stitching Seams

Two different brands of imported sewing threads commonly used for garment production in Ghana were bought from the market and labelled A′ and B′ for ethical reasons.

iii. Soap for Washing Tests

Key bar soap, produced by Uniliver, Ghana limited, was purchased from the market and used for washing the specimens.

3.5.2 Instruments used for Phase Two Data Collection

The instruments employed for seam evaluation were:

i. Butterfly hand sewing machine with needle size 14. The hand sewing machine is mostly used among seamstresses in Ghana and the 14 needle size is the type most of them employ in stitching.
ii. Standard Launder-Ometer (Gyrowash 315).

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iii. Tensile testing machine (Mark-10 Force Gauge Model M5-500).

iv. Pair of scissors.

3.5.3 Preparation of Specimens for Phase Two of the Study

The 301 lock-stitch which is the most common stitch used by seamstresses in Ghana and indicated by Olsen (2008) as the standard laboratory stitch used for testing seam quality was used to stitch the specimens. Plain seam (301-SSa-1 seam type) was used in this study and the seams were made with a Butterfly hand sewing machine using needle size 14. The sewing thread brands (A′ and B′) were used as both upper and under threads in stitching. The stitch densities used were 10, 12 and 14 with seam allowance of 2cm. Both GSA and ISO made no reference to seam allowance requirements while reviewing literature. It was however indicated in the ISO 13935-1:2014 that the researcher would have to decide on the seam allowance to use. Gribaa et al. (2006) stated that a yarn in a fabric can pull out of the seam from the edge, therefore proper selection of seam allowance is necessary to minimize or prevent seam slippage. It was observed in pretesting that with 2cm seam allowance, breaking of stitches will occur without yarns in the fabric slipping through the seam allowance, hence the 2cm chosen.

The stitch densities used for the study were informed by the recommended range for medium weight fabrics indicated by Brown and Rice (1998) and Chowdhary and Poynor (2006) which ranges from 12-14 stitches per inch. The choice of SPIs was also informed by the researcher's observation of the SPI ranges commonly used by seamstresses in Ghana.

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Following ISO 13935-1 (2014), 40 pieces of fabric specimens (20 in warp, 20 in weft, see Table 5, Appendix E for details), each measuring 19cm×42cm were randomly cut from the 11 metres of fabric sample. The specimens were folded in half with the fold parallel to the 42cm direction and the seams made in this direction (Figure 3.3, page 119) as indicated by ISO 13935-1 (2014). Out of the 40 stitched fabric pieces, 240 specimens 15cm×6cm were cut and 4 cuts of 1.5cm length at 1cm distance from the seam line as shown in Figure 3.4, page 120, were made. The areas shaded and labelled 1.5cm (Figure 3.4) were frayed so that a final specimen width of 3cm was obtained for the investigations. Table 5 (Appendix E) provides the details of the specimens that were used for the phase two of the study and Table 6 (Appendix F) shows the details of the labels for the specimens done for easy identification. It was indicated in the ISO 13935-1 (2014) that either warp, or weft seams or both could be tested. The researcher decided to test both, because in sewing the school uniforms some seams may be in the warp direction as in side seams and others may be in the weft as in shoulder seams.

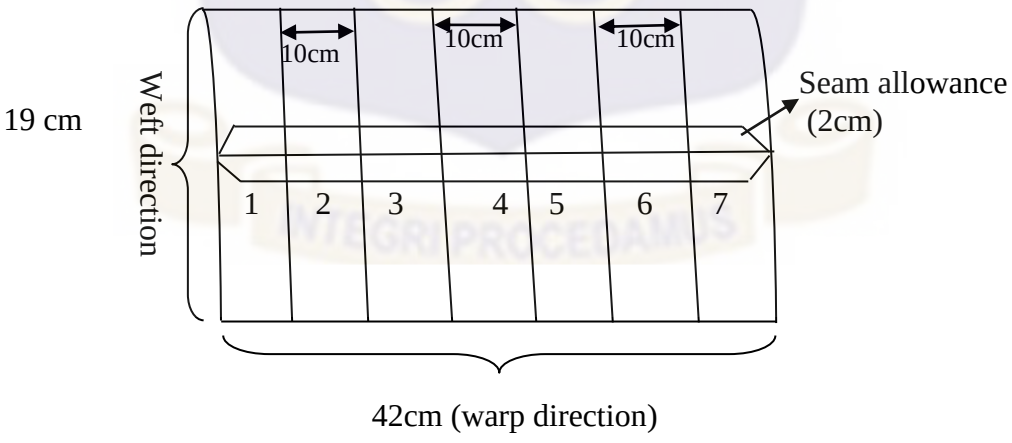


Figure 3.3:The piece of fabric from which 5 specimens were taken at random for each SPI test

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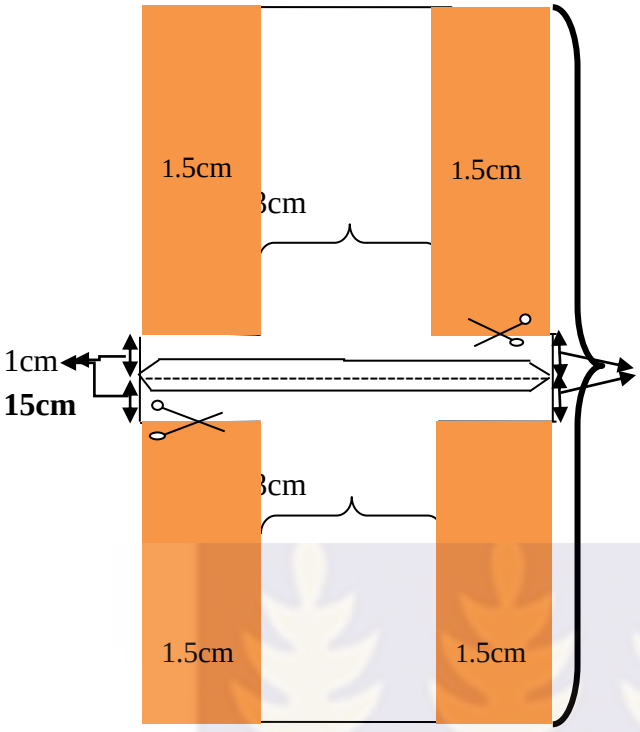


Figure 3.4: Final test specimen for seam strength and elongation

3.5.4 Experimental Procedure: Phase Two

All specimens for the investigations were conditioned for 24 hours in a relaxed state at a relative humidity of 65 ± 2% and a temperature of 21°± 1°C as indicated in the ISO 13935-1 (2014). The parameters determined were:

i. Seams Strength, Elongation and Efficiency

The tensile testing machine (Mark-10 Force Gauge Model M5-500) was used to test seam strength and elongation of the specimens. The gauge length of the tensile testing machine was 100mm and the rate of extension or the speed was 25mm/minute. The force at break (strength) was recorded in Newtons (N) while the extension at break (elongation) was recorded in millimetres for each specimen in both the warp and the

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weft directions after each wash cycle. These were done for the unwashed specimens as well. Seam elongation was calculated using the formula, viz:

$$\text{Breaking elongation} = \frac{\text{Elongation}}{\text{Original length}} \times 100$$

And as used by Chowdhary and Poynor (2006), LaPere (2006) and Sarhan (2013).

Seam efficiency was calculated using the formula adopted from Chowdhary and Poynor (2006), LaPere (2006), Sarhan (2013) and Choudhary and Goel (2013):

$$\text{Seam Efficiency} = \frac{\text{Seam strength}}{\text{Fabric strength}} \times 100$$

ii. Sewing Threads Linear Density

The ISO standard (ISO 2060:1994, Textiles- yarn from packages: determination of linear density (mass per unit length) by the skein method) was employed for testing the linear densities of the sewing threads. One reel of each brand of the sewing thread selected for the study was used. With the aid of a thread reel the length of each brand of thread was determined. After that, the full length of each brand of thread was weighed to establish their weights in grams. The linear density of each sewing thread brand was calculated with the equation: $Ttc = \frac{mc \times 1000}{L}$

Where, mc = the mass, in grams, of the test skein

L =the length, in meters of the test skein (ISO 2060, 1994).

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3.5.4.1 Washing Procedures for Phase Two of the Study

The procedures used by Ghana Standards Authority (GSA) Textile testing Laboratory for preparation of soap solution and washing for washing tests were followed.

3.5.4.1.1 Preparation of Soap Solution

A stock solution of key soap was prepared for washing the specimens. Based on the weight of the specimens washed, 39 grams of soap was dissolved in 9.6L of water and that was able to wash all the specimens in the three wash cycles.

3.5.4.1.2 Washing using the Launder-Ometer

The specimens to be washed were subjected to washing in the Standard Launder-Ometer (Gyrowash 315) with the solution prepared from the key soap. The washing was done at 60°Ctemperaturefor 30 minutes and followed by rinsing in each wash cycle.

3.5.4.3 Drying of Specimens

The washed specimens were dried at room temperature. The specimens after drying were not ironed, but were tested for the various parameters identified.

3.6 Data Analysis and Presentation

The data for the study was analysed by the use of the Predictive Analytical Software (SPSS) for Windows version 22. Means and standard deviations of the fabrics performance characteristics such as yarn count, weight, strength, elongation and yarn linear density as well as that of the sewing threads were calculated and presented.

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Inferential statistics (Analysis of Variance and Independent samples *t*-test at 0.05 alpha levels) were employed in testing the hypotheses. These are statistical tools used in measuring differences, and the purpose of testing the hypotheses was to establish if any differences existed between and among the groups identified in the study.

To test hypotheses 1(a, b, c, d, e), 2(a, b, c, d) 3(b, c), 4(b, c) and 5(b, c), One-Way ANOVA was employed. With regard to hypotheses 3(a), 4(a), and 5(a) Independent samples t-test was used where thread brands were taken against the dependent variables (seam strength, elongation and efficiency). For hypotheses 6a, b and c, which were to establish the combined effect of the independent variables (thread brands, stitch densities and washing cycles) on the dependent variables (seam strength, elongation and efficiency), 3-Way Analysis of Variance was used where the independent variables were taken against each dependent variable. However, In the case of a statistical significance, a Post Hoc analysis using Tuckey HSD was conducted to further establish the variables that recorded significant differences. The results were presented in tables and graphs.

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results acquired from the analysis of the data for the study are presented and discussed. The chapter is structured under phases one and two of the study and followed with discussion of the results. The phase one (fabric performance evaluation) is presented under the following headings:

a. Performance properties of fabrics and standard specifications for uniform fabrics with which the performance characteristics of the fabrics were compared
b. Testing of Hypothesis 1
c. Testing of Hypothesis 2

Phase two is also structured under:

a. Performance characteristics of fabric B2 and sewing threads
b. Differences between fabric tensile properties (strength and elongation) and seam tensile properties (strength and elongation)
c. Testing of Hypotheses 3, 4 and 5
d. Testing of Hypothesis 6

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4.2 Results Phase One: Fabric Performance Evaluation

4.2.1 Performance Properties of the Fabrics and Standard Specifications for Uniform Fabrics with which the Performance Characteristics of the Fabrics were Compared

To determine whether the investigated fabrics met the required standard specifications for uniform fabrics, the results obtained from evaluating the three brands of fabrics performance characteristics had to be compared to the specifications outlined in GS 970:2009 (Textiles- specification for fabrics for shirts and uniforms). The test results for the parameters investigated are shown in Tables 4.1, page 126 and 4.2, page 129 with the standard specification presented in Table 4.3, page 131.

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Table 4.1: Results for the performance properties of the fabrics studied

Fabric Brands	Weave type	Percentage (%) Fibre content	Mean Weight (g/m^2)	Colourfastness to washing (Grey scale)				Mean Shrinkage (%)		Mean Yarn count		Mean Yarn linear density (Tex)		Mean Breaking strength (Newton)		Mean Breaking elongation (%)	
				Change in colour	Staining												
					Cotton	Polyester	Polyamide	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
A1	Plain	35 viscose 65 polyester	174	5	4-5	5	4-5	2	2	56	50	82	46	379	371	27	35
A2	Plain	35 viscose 65 polyester	175	5	4-5	4-5	4-5	2	2	57	52	84	45	461	382	27	40
B1	Plain	11 cotton 89 polyester	138	4-5	4	4	4-5	2	2	61	45	79	45	359	358	29	35
B2	Plain	21 cotton 79 polyester	138	5	4	5	4-5	2	2	62	46	78	43	401	372	31	44
C1	Plain	1 cotton 99 polyester	121	5	4-5	4	3-4	2	2	81	68	41	18	341	318	27	39
C2	Plain	2 cotton 98 polyester	107	5	4-5	4	3	2	2	79	66	42	19	354	278	24	31

A1, B1, C1= the Chocolate 4/saddle brown colours of fabric brands A, B and C, A2, B2, C2=the sandy brown colours of fabric brands A, B and C

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Weave Type, Weight and Fibre Types of the Fabrics

Table 4.1 indicates that the fabrics were all plain woven. Fabric A2 had the highest weight (M=175g/m^2) followed by A1 (M=174g/m^2) and C2 had the lowest weight (M=107g/m^2). In terms of fibre content, each of the fabrics A1 and A2 had 35% and 65% viscose and polyester fibres. Fabric B1 contained 11% cotton and 89% polyester, but B2, from the same producer as B1was 21% cotton, 79% polyester. Fabric C1 contained 1% cotton and 99% polyester whiles C2 had 2% cotton and 98% polyester.

Colourfastness to Washing of the Fabrics

Table 4.1 shows that apart from fabric B1 which had an average grey scale value of4-5, the rest had the same grey scale value of 5. In terms of staining on cotton, fabrics A1, A2, C1 and C2 had average grey scale reading of 4-5 while B1 and B2 had a value of 4. For staining on polyester, fabrics A1 and B2 obtained the best results with the grey scale value of 5 followed by A2 (Table 4.1).

Dimensional Stability to Washing of the Fabrics

Table 4.1 indicates that the average percentage shrinkage in both directions (warp and weft) of all the fabrics studied was 2%.

Tensile Strength of the Fabrics

Table 4.1 portrays that fabric A2 had average strength of 461N and 382N in the warp and weft directions respectively. These values were the highest in both directions of the fabrics studied. Fabric C1 had the lowest mean value for strength in the warp (M=341N) andC2 obtained the lowest strength value of 278N in the weft direction.

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Yarn Count and Yarn Linear Density of the Fabrics

With regard to yarn count, Table 4.1 shows that fabric C1 had the highest number of yarns in the warp direction (M= 81), followed by C2 (M= 79) and A1 (M= 56) had the lowest number of yarns. In the weft direction, fabric C1 had the highest count(M= 68) and fabrics B1 and B2 had the least numbers of yarns. For yarn linear density, in both the warp and weft directions, fabrics A1and A2 had the highest mean value of yarn linear density with C1 obtaining the lowest mean linear density values (warp= 41, weft= 18).

Elongation of the Fabrics

Table 4.1 indicates that in the warp direction, fabric B2 had the highest percentage elongation of 31% while C2 had the least value of 24%. For the weft direction, fabric B2 had the highest percentage elongation of 44% and C2 had the lowest value of 31%.

Absorbency of the Fabrics

Table 4.2, page 129, presents the absorbency results for the brands of fabrics used for the study. As seen in Table 4.2, brand A used the least amount of time to completely absorb the drop of water placed on it while brand C used the highest amount of time yet not able to absorb the water drop completely. Figures 4.1 and 4.2 indicate the complete water absorption of fabric brands A and B and Figure 4.3, page 130, shows the incomplete water absorption of brand C.

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Table 4.2: Absorbency results of the fabrics

Fabric Brands	Time for water absorption
A1	15 seconds (complete water absorption)
A2	15 seconds (complete water absorption)
B1	28 seconds (complete water absorption)
B2	35 seconds (complete water absorption)
C1	1 minute 15 seconds (absorption incomplete)
C2	1 minute 16 seconds (absorption incomplete)

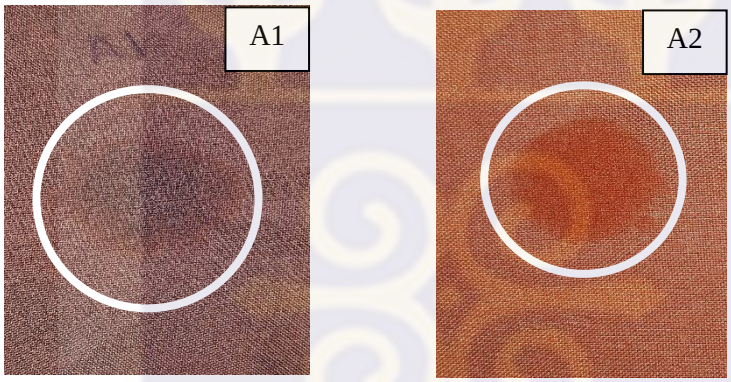


Figure 4.1:Complete water absorption in both Fabrics A1 and A2

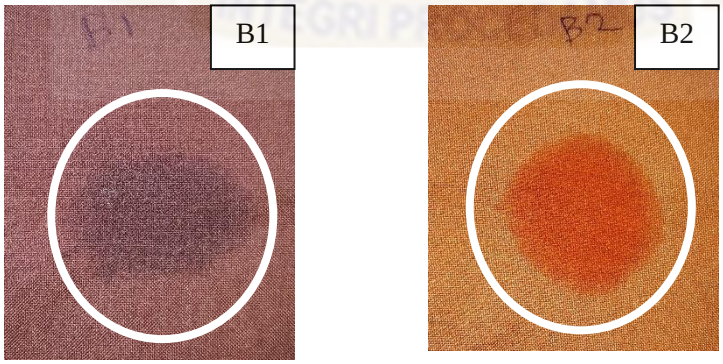


Figure 4.2: Complete water absorption in both Fabrics B1 and B2

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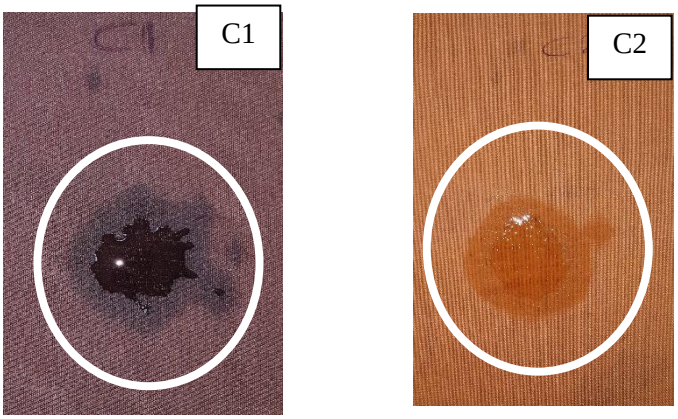


Figure 4.3: Incomplete water absorption in both Fabrics C1 and C2

The Standard Specification with which the Uniform Fabrics Studied were Compared

Table 4.3, page 131, presents the standard specifications with which the test results for the parameters studied were compared. A fabric that meets all the standard requirements stated in Table 4.3 is suitable to be used for school uniform (GS 970, 2009). In the standard GS 970:2009, letters of the alphabets are used to represent the fibre content of fabrics. They are:

i. C stands for 100% cellulose.
ii. CR is for a cellulose fibre and synthetic fibre blend containing more than 50% cellulose fibre.
iii. SR is for a cellulosic fibre and synthetic fibre blend fabric containing less than 50% cellulosic fibre.

From the assessment made on the three fabric brands, their fibre content placed them under the SR. For that reason, the parameters values presented in Table 4.3 cover only fabrics that fall under the SR.

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Table 4.3: Standard specifications for parameters indicated in GS 970:2009 (Textile specification for shirts and uniform fabrics)

Type of fibre	Weave type	Mass per unit area (g/m^2)	Breaking strength (N) (min)		Colourfastness to washing				Dimensional change on washing (shrinkage) (%)max
			Warp	Weft	Colour change	Staining of			
						cotton	Polyester	Polyamid	
SR (Fabric blend containing less than 50% cellulose fibre)	Could be woven or knitted	>280 235-279 190-234 140-189 <140	1300 1100 1000 700 200	750 600 500 400 200	4	3- 4	3	-	±2

Table 4.3 indicates that a suitable fabric for school uniform could be woven or knitted. The mass per unit area (weight) of such fabric could be greater than $280g/m^2$ and less than $140g/m^2$. The minimum strength values of fabrics with weight values greater than $280g/m^2$ should be 1300N in the warp and 750N in the weft directions. Fabrics with weight values less than $140g/m^2$ should have minimum strength values of 200N in both the warp and weft directions. In terms of colourfastness to washing (colour change) a suitable uniform fabric should have a grey scale value of 4. For staining, the grey scale reading for cotton should be3-4, 3 for polyester and no value

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was indicated for polyamide. The percentage dimensional stability value for a suitable uniform fabric is ±2% maximum.

4.2.2 Testing of Hypothesis 1: *There is no significant difference among the a) Weights, b) Strengths, c) Elongations d) Shrinkage and e) Yarn counts of three different Brands of Fabrics used for the Construction Of Ghanaian Public Basic School Uniforms*

One-way Analysis of Variance (ANOVA) was used to test hypotheses 1 a, b, c, d and e to establish whether significant differences existed among the fabric brands and their performance properties (weight, strength, elongation, shrinkage and yarn count). The results are presented in Table 4.4, page 133.

Results for Hypothesis 1a

Table 4.4 shows that significant differences existed among the weights of the fabrics ($p=0.001$). Post Hoc analysis to determine between group variability revealed that differences were significant between all groups (Table 7, Appendix G, page 234).

Results for Hypothesis 1b

Table 4.4 indicates that significant differences existed among the strength of the fabrics. Post Hoc analysis to determine between group differences showed that differences were significant between fabrics A2×A1, A2×B1, A2×C1, A2×C2, B2×A1 and B2×C2 for the warp direction (Table 8, Appendix G, page 235). In the weft direction, differences were significant between fabrics A1×C2, A2×B1, A2×C1, A2×C2, B1×C2, B2×C2 and C1×C2 (Table 8, Appendix G).

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Table 4.4: ANOVA results for differences among fabric brands and their weights, strengths, elongations, shrinkage and yarn counts

Fabric Brands / Parameter	A1		A2		B1		B2		C1		C2		MS	df	*F*	*p-value*
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD				
Weight (g/m^2)	172	2.099	174	1.488	138	0.948	139	0.667	121	1.315	107	2.276	14387.79	5	5803.37	0.001*
Strength (Newton)																
Warp	382	56.937	464	28.699	386	51.464	430	50.671	388	53.424	369	40.731	25884.17	5	11.26	0.001*
Weft	333	59.342	365	29.078	324	39.784	354	44.848	328	19.228	287	25.198	14836.29	5	9.928	0.001*
Elongation (%)																
Warp	27	3.758	29	4.868	32	7.983	31	3.131	32	8.103	26	4.785	139.370	5	4.183	0.001*
Weft	35	4.839	40	3.543	37	3.274	42	4.353	32	6.501	34	3.397	256.114	5	12.865	0.001*
Shrinkage (%)																
Warp	1	0.883	2	0.458	2	0.593	0.8	0.561	1	0.915	1	1.069	4.933	5	8.136	0.001*
Weft	2	0.834	2	0.507	1	0.817	1	0.724	2	0.915	1	0.594	5.324	5	9.584	0.001*
Yarn count																
Warp	56	4.147	58	2.775	62	1.140	62	0.894	82	2.387	80	1.483	633.520	5	108.915	0.001*
Weft	50	2.864	52	2.302	45	0.894	46	1.789	69	2.608	67	3.131	542.593	5	95.471	0.001*

**Significant $p<0.05$, M= Mean, SD= Standard Deviation, MS= Mean Square*

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Results for Hypothesis 1c

Table 4.4 indicates significant differences among the fabrics in both directions (warp and weft) with regard to elongation. The *p-values* were 0.001 and 0.001 for the warp and weft directions respectively. Post Hoc analysis to determine between group differences revealed that differences were significant between fabrics B1×A1, B1×C2, C1×A1 and C1×C2 for the warp direction (Table 9, Appendix G, page 236). In the weft direction, difference were significant for fabrics A2×A1, A2×C1, A2×C2, B2×A1, B2×B1, B2×C1 and B2×C2 (Table 9, Appendix G).

Results for Hypothesis 1d

Table 4.4 shows that for dimensional stability, significant differences existed among the fabrics studied in both the warp (*p=0.001*) and weft (*p=0.001*) directions. Post Hoc analysis of the data to establish between group differences showed that in the warp direction, differences were significant between fabrics A2×A1, A2×B2, A2×C1, A2×C2, B1×B2 and B1×C2 while in the weft direction, differences were noted between fabrics A1×B1, A1×B2, A1× C1, A1×C2, A2×B1, A2×B2, A2×C1and A2×C2 (Table 10, Appendix G, page 237).

Results for Hypothesis 1e

As seen in Table 4.4, page 133, significant differences existed among the fabrics in both the warp (*p=0.001*) and weft (*p=0.001*) directions with regard to yarn count. Post Hoc analysis performed to establish between group differences, showed that differences were significant between all groups (Table 11, Appendix G, page 238). Figure 4.4illustrates the differences among the fabrics yarn counts.

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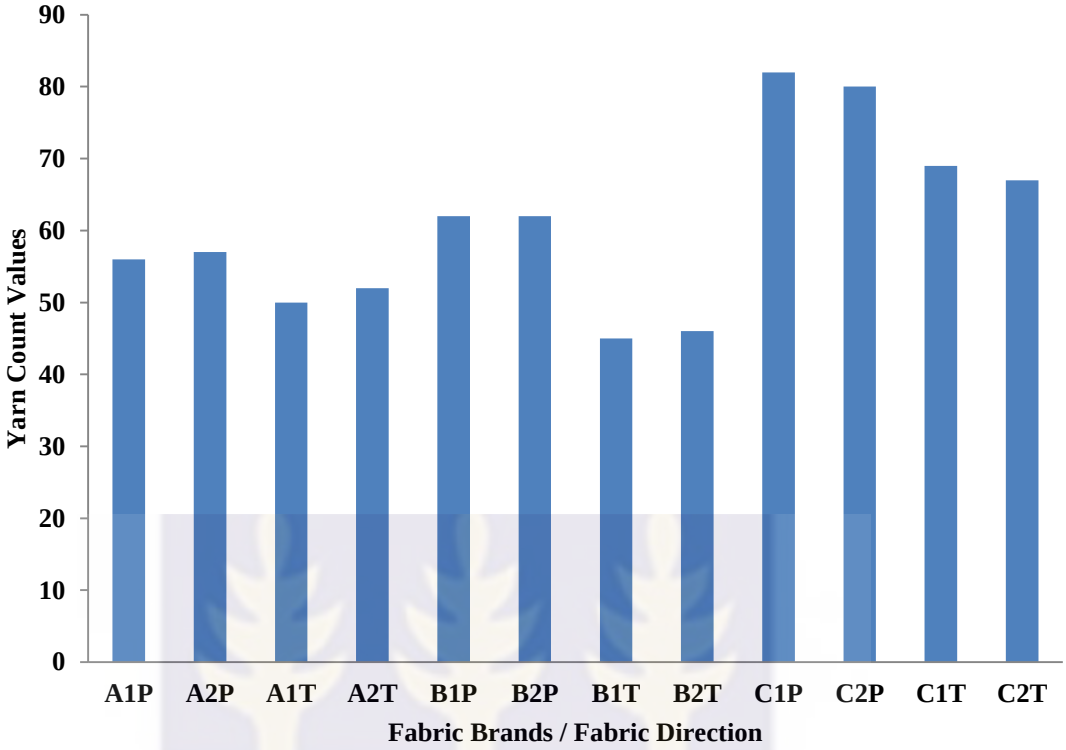


Figure 4.4. Differences among the fabrics yarn counts

4.2.3 Testing of Hypothesis 2: *There is no significant difference between the number of times of washing (wash cycles) and the a) Strengths, b) Elongations, c) Weights and d) Shrinkage of the three different Brands of Fabrics used for Ghanaian Public Basic School Uniforms*

One-way ANOVA was used to test hypothesis 2 a, b, c and d to determine whether significant differences existed between wash cycles and the fabrics performance characteristics (strength, elongation, weight and shrinkage). The results are provided in Table 4.5, page 137, Figures 4.5, page 138, and 4.6, page 139, illustrate the differences between wash cycles and the strengths and elongations of the fabrics studied.

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Results for Hypothesis 2a

Table 4.5 shows that significant difference existed between number of times of washing (wash cycle) and strength in the weft (*F=4.175, df=3, p=0.008),* but not in the warp (*F=2.779, df=3, p=0.041*) directions of the fabrics. The mean strength values indicate that, in the weft direction, unwashed specimens (M=348N) had the highest strength while 3rd wash specimens (M=314N) had the least strength. In the warp direction, 2nd wash specimens had the highest strength (M=421N) while unwashed specimens (M=381N) had the least strength. Post Hoc analysis performed to determine between group differences revealed that in the weft direction, differences were significant between unwashed and 3rd wash specimens (Table 12, Appendix G, page 239).

Figure 4.5 illustrates the trend of increase or decrease in the strength of each fabric as washing progressed. For instance, it can be seen from Figure 4.5 that for fabric A1, strength in the warp direction decreased after 1stwash, increased after the 2nd wash and decreased after the 3rdwash. This same trend can be noted with fabrics A2 and B2 in their weft directions. Fabrics A2, B1 and C1 had a trend of increased strength after 1st and 2ndwashes and decreased strength after the 3rdwash in their warp directions. For fabric B1, in the weft direction, a trend of decrease in strength after the 1st, 2nd and 3rdwashes was observed (Figure 4.5).

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Table 4.5: ANOVA results for fabrics strengths, elongation, weights, and shrinkage by wash cycles

Wash Cycle / Parameter	Unwashed		1st Wash		2nd Wash		3rd Wash		MS	df	*F*	*p-value*
	M	SD	M	SD	M	SD	M	SD				
Strength (Newton)												
Warp	381	66.590	411	55.459	421	46.184	400	54.338	8749.469	3	2.779	0.041
Weft	348	49.934	322	39.102	342	45.604	314	38.838	7943.319	3	4.175	0.008*
Elongation (%)												
Warp	27	3.376	31	5.136	28	4.184	32	9.085	166.129	3	4.822	0.004*
Weft	37	6.379	38	5.911	35	5.482	36	3.287	57.351	3	1.969	0.146
Weight (g/m^2)	142	25.671	142	25.545	142	24.640	141	23.897	5.895	3	0.009	0.999
Shrinkage (%)												
Warp			2	0.898	1	0.907	1	0.964	0.700	2	0.821	0.443
Weft			2	0.776	2	0.889	2	1.040	0.744	2	0.902	0.337

**Significant p<0.05, M= Mean, SD= Standard Deviation, MS= Mean Square*

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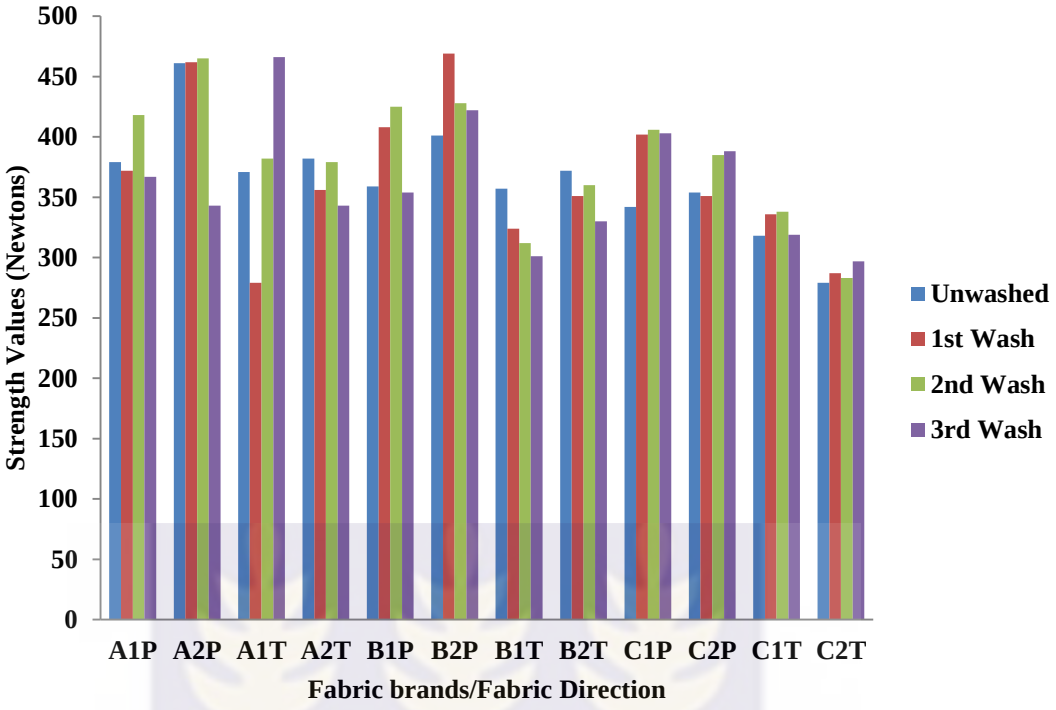


Figure 4.5: Fabrics strengths by number of wash cycles

Results for Hypothesis 2b

With regard to elongation, Table 4.5 indicates that significant differences existed between the number of times of washing in the warp (*F=4.822, df=3, p=0.004*), but not in the weft (*F=1.969, df=3, p= 0.146*) directions. The mean elongation values in Table 4.5 show that, in the weft direction, elongation increased after the first wash (M=38%), decreased after the second wash (M=35%) and increased after the third wash (M=36%). The same trend was established with the warp direction as well. Post Hoc analysis conducted to determine between group differences in the warp direction showed that differences were significant between 3rd Wash × Unwashed and 3rd Wash × 2nd wash specimens (Table 12, Appendix G).

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Figure 4.6 illustrates the trend of increase or decrease with regard to fabric elongation and washing. It can be noted that fabrics A1, B1 and C2 in their weft direction and fabrics B1and C2 in their warp direction had a trend of increased elongation after first wash, decrease elongation after second wash and increased elongation after the third wash. Fabric A2, in the warp and weft directions experienced percentage increase in elongation after the first wash, decrease after the second wash and decrease after the third wash (Figure 4.6).

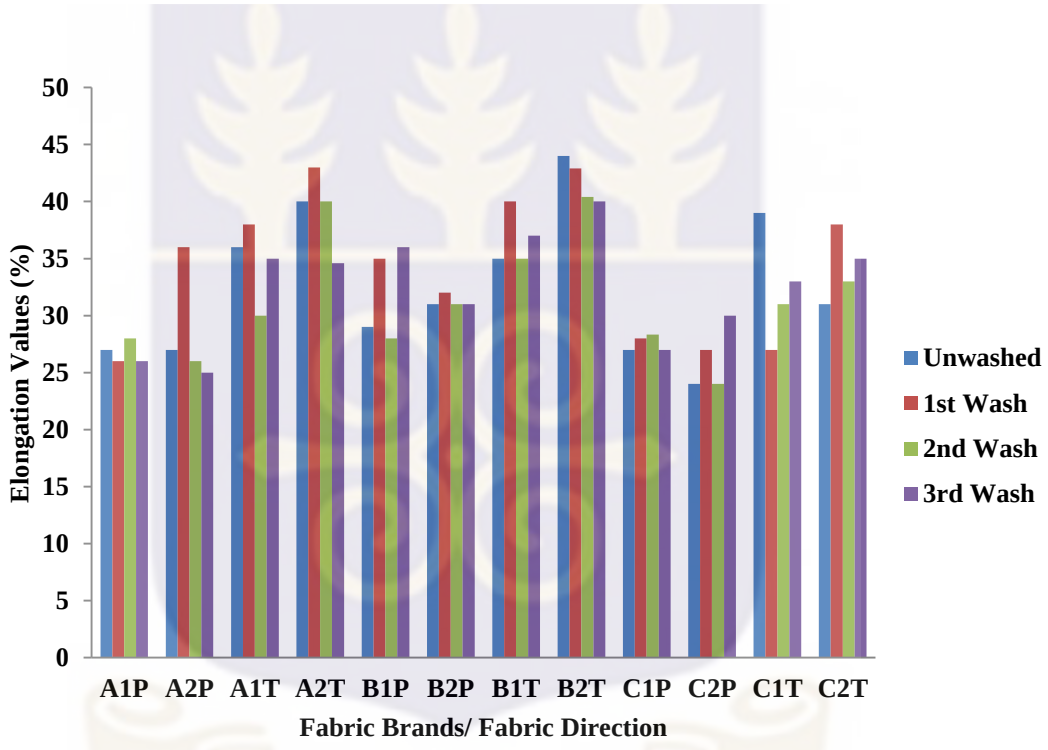


Figure 4.6: Fabrics elongations by number of wash cycles

Results for Hypothesis 2c

Table 4.5indicates no significant difference between the number of times of washing and weight of the fabrics. The mean weight values however, showed a slight decrease in weight of the fabrics after the third wash (M=141g/m^2) (Table 4.5).

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Results for Hypothesis 2d

As shown in Table 4.5 no significant difference existed between the number of times of washing and shrinkage of the fabrics both in the warp (*F=0.821, df=2, p=0.443*) and the weft (*F=0.902, df=2, p=0.337*) directions. The mean scores from the warp direction however, indicate that shrinkage reduced after the second and third washes.

Colourfastness to Washing of Fabrics

Colourfastness after each wash cycle was assessed with the help of ISO grey scale for colour change and staining. The average values are shown in Tables 4.6, page 141 and 4.7, page 142. Table 4.6 indicates that after the first wash, no change in colour was observed in fabrics A1, A2, B2, C1 and C2 with average values of 5 on the grey scale. Surprisingly all the fabrics obtained the same average value of 4-5 on the grey scale after the second wash indicating that wash cycle had a slight influence on change in colour (Table 4.6). With regard to the third wash, fabrics A2, B2, C1 and C2 had same average value of 4-5 on the grey scale as obtained after the second wash. Fabrics A1 and B1 also obtained same average values of 4 (Table 4.6).

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Table 4.6: Average colour change values for fabric specimens

Fabric Brand	Average colour change values		
	1st Wash	2nd Wash	3rd Wash
A1	5	4-5	4
A2	5	4-5	4-5
B1	4-5	4-5	4
B2	5	4-5	4-5
C1	5	4-5	4-5
C2	5	4-5	4-5

With regard to fastness to staining, Table 4.7 indicates that after the third wash almost all the multi-fibre fabric specimens had grey-scale values of 5 for staining indicating no contrast. However, among the fabrics studied, C1 and C2 did not perform very well with regard to staining on nylon and acetate after the first wash as C1 and C2 had values of 3 each on acetate. In terms of staining on nylon after the first wash, C2 had a value of 3, but C1 had a value of 3-4 (Table 4.7). Fabrics A1 and A2also had an average value of 3-4 for staining on acetate after the first wash (Table 4.7).

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Table 4.7: Average grey scale values for staining

Fabric Brand	A1			A2			B1			B2			C1			C2		
Staining Fabrics	**1st Wash**	**2nd Wash**	**3rd Wash**	**1st Wash**	**2nd Wash**	**3rd Wash**	**1st Wash**	**2nd Wash**	**3rd Wash**	**1st Wash**	**2nd Wash**	**3rd Wash**	**1st Wash**	**2nd Wash**	**3rd Wash**	**1st Wash**	**2nd Wash**	**3rd Wash**
Wool	5	5	5	4-5	5	5	4-5	5	5	4-5	5	4-5	4-5	5	5	4-5	4-5	5
Acrylic	5	5	5	5	5	5	4-5	4-5	5	4-5	5	5	5	4-5	5	4-5	5	5
Polyester	5	4-5	5	4-5	5	5	4	5	5	5	5	5	4	5	5	4	4-5	5
Nylon	4-5	4-5	5	4-5	4-5	5	4-5	5	5	4-5	4-5	5	3-4	4-5	5	3	4-5	5
Cotton	4-5	4-5	5	4	4-5	5	4	5	5	4	4-5	5	4-5	4-5	5	4-5	4-5	5
Acetate	3-4	4-5	5	3-4	4-5	5	4	4-5	5	4	4	5	3	4-5	5	3	4-5	5

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4.3 Results Phase Two: Seam Performance Evaluation

4.3.1 Performance Characteristics of Fabric B2 and Sewing Threads

The fabric was 21% cottonand79% polyester with a plain weave of 1x1 repeat in both directions. The sewing threads were both 100% polyester. Table 4.8, page 143, shows that the fabric had higher yarn count in the warp direction (M= 62) than the weft (M= 46). It had higher linear density in the warp direction (M= 78 Tex) than in the weft direction (M= 42 Tex).

Table 4.8: Performance attributes of fabric B2 and sewing threads

Attribute	N	M	SD
Fabric yarn count			
Warp	5	62	0.894
Weft	5	46	1.289
Fabric Weight	5	138g/m^2	0.837
Yarn linear density			
Warp	1	78Tex	-
Weft	5	42Tex	0.548
Breaking strength			
Warp	5	401N	49.193
Weft	5	372N	36.594
Breaking Elongation			
Warp	5	31%	3.422
Weft	5	44%	6.589
Sewing Threads	**A′**	**B′**	
Linear density	30Tex	44Tex	

N=Number of specimens; M=Mean; SD=Standard Deviation

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The strength of the fabric in the warp direction was higher (M= 401N) than in the weft direction (M= 372N). For elongation, the weft direction was greater (M= 44%) than the warp direction (M= 31%). The linear densities of the sewing threads were 30tex and 44tex for brands A′ and B′ respectively (Table 4.8).

4.3.2 Differences between Fabric Tensile Properties (Strength and Elongation) and Seam Tensile Properties (Strength and Elongation)

To determine whether differences existed between fabric tensile properties (strength and elongation) and seam tensile properties (strength and elongation) after three wash cycles, means and standard deviations were used and the results are provided in Tables 4.9, page 145 and 4.10, page 147.

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Table 4.9: Difference between fabric strength and seam strength after three wash cycles

Seam (weft)	A′10		A′12		A′14		B′10		B′12		B′14		Fabric (warp)	
	M(N)	SD	M(N)	SD	M(N)	SD	M(N)	SD	M(N)	SD	M(N)	SD	M(N)	SD
Unwashed	153	20.897	210	13.863	235	20.184	196	33.402	249	13.479	352	9.421	401	49.193
1st wash	175	14.374	190	19.969	234	6.140	223	17.789	237	13.493	319	19.018	469	38.635
2nd wash	146	2.162	181	20.849	204	16.155	206	23.076	258	14.746	317	16.571	428	53.801
3rd wash	174	12.245	180	24.534	231	10.549	224	22.575	224	13.650	318	9.278	422	47.766
Seam (warp)													**Fabric (weft)**	
Unwashed	177	15.017	184	13.520	209	29.976	219	6.551	218	16.549	285	60.108	372	36.595
1st wash	138	32.437	188	13.517	195	27.584	159	18.853	187	16.107	233	22.775	351	46.531
2nd wash	151	7.961	154	17.068	227	27.762	171	34.243	183	30.549	237	12.467	360	14.381
3rd wash	161	21.953	172	18.780	196	35.995	196	21.626	175	13.102	225	49.595	330	68.408

M=Mean, N=Newton, SD=Standard Deviation

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Differences between Fabric Strength and Seam Strength after Wash Cycles

Table 4.9 indicates that in the warp direction, the fabric specimens had greater strength than the weft seams in the two thread brands (A′ and B′) stitched in the three SPIs (10, 12 and 14) throughout the wash cycles. With regard to the weft direction, the fabric specimens had greater strength than the warp seams stitched with both brands of threads (A′ and B′) in the three SPIs (10, 12 and 14)all through the wash cycles.

Difference between Fabric Elongation and Seam Elongation after Wash Cycles

Table 4.10shows that, apart from seams stitched with brand B′ sewing thread in 14 SPI, the fabric had higher percentage elongations in the warp direction than the weft seams stitched with both brands of threads (A′ and B′) in the three SPIs (10, 12 and 14) throughout the wash cycles.

When the specimens were unwashed, weft fabric specimens had higher percentage elongations than the warp seams stitched with both brands of threads in the three SPIs, but not after first, second and third washes. After the first wash through to the third wash, the specimens stitched with sewing thread brand B′ in 14 SPI had higher percentage elongations than the fabric. After the first wash, specimens stitched with brand A′ thread in 14 SPI had the same percentage elongation as the fabric and higher percentage elongations after the second and third washes. After the second wash, specimens stitched with brand B′ thread in 12 SPI had the same percentage elongation as the fabric (Table 4.10).

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Table 4.10: Differences between fabric elongation and seam elongation after three wash cycles

Seam (weft)	A′10		A′12		A′14		B′10		B′12		B′14		**Fabric (warp)**	
	M(%)	SD	M(%)	SD	M(%)	SD	M(%)	SD	M(%)	SD	M(%)	SD	M(%)	SD
Unwashed	18	2.253	19	2.566	26	3.553	19	2.659	21	2.236	36	2.401	31	3.422
1st wash	18	1.601	18	1.765	22	2.819	22	2.312	22	1.557	36	3.259	32	1.139
2nd wash	20	0.746	19	3.061	22	1.476	21	2.472	22	0.699	34	2.485	31	4.884
3rd wash	19	1.394	19	2.041	22	1.604	20	2.311	22	2.313	35	1.531	31	2.715
Seam (warp)													**Fabric (weft)**	
Unwashed	32	2.593	30	2.172	38	3.446	32	1.603	32	1.087	43	3.961	44	6.587
1st wash	28	3.699	40	3.302	43	5.263	33	2.636	40	3.799	45	0.943	43	4.061
2nd wash	33	3.554	33	3.612	49	5.623	36	5.546	40	4.738	54	2.317	40	2.376
3rd wash	32	2.923	35	5.786	45	4.816	39	6.371	37	3.249	46	3.297	40	3.421

M=Mean, SD= Standard Deviation

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4.3.3 Testing of Hypotheses 3(a, b, c), 4(a, b, c),and 5(a, b, c)

To determine whether differences existed between thread brands, stitch densities and wash cycles with regard to seam performance properties (strength, efficiency and elongation), hypotheses 3(a, b, c), 4(a, b, c)and 5(a, b, c) were tested using inferential statistics. The results are provided in Tables 4.11 to 4.13. Figures 4.7 to 4.11 illustrate the differences between thread brands, stitch densities and wash cycles and seam strength, efficiency and elongation.

4.3.3.1 Testing of Hypotheses 3a, 4a and 5a: *There is no significant difference between sewing thread brands with regard to 3a) Seam Strength, 4a) Seam Efficiency and 5a) Seam Elongation of a Suitable Fabric for Ghanaian Public Basic Schools Uniforms*

In order to test Hypotheses 3a, 4a and 5a, which sought to establish whether significant differences existed between sewing thread brands and seam strength, efficiency and elongation, independent samples *t*-test was employed. The results are presented in Table 4.11, page 149.

Results for Hypothesis 3a

Table 4.11 indicates that significant differences existed between the two sewing thread brands in relation to seam strength in both the warp (*t=-3.924, df=118, p=0.001*) and weft (*t*=-8.691, *df=118, p=0.001*) seams. In both directions, brand B′ had greater seam strength than brand A′. Figure 4.7 illustrates the differences between sewing thread brands in relation to seam strength.

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Table 4.11: Means, Standard Deviations, *T*-values and *P*-values for seam strength, efficiency and elongation by two sewing thread brands

Thread Brands / Parameter	A′		B′		df	*t-value*	*p-value*
	M	SD	M	SD			
Strength (Newton)							
Warp	179	33.283	206	43.012	118	-3.924	0.001*
Weft	193	32.767	262	52.239	118	-8.691	0.001*
Efficiency (%)							
Warp	51	9.453	60	11.664	118	-4.023	0.001*
Weft	45	8.139	61	13.023	118	-8.202	0.001*
Elongation (%)							
Warp	36	7.314	40	6.986	118	-2.481	0.015*
Weft	20	3.140	26	7.098	118	-5.400	0.001*

**Significant p<0.05, M=Mean, SD=Standard Deviation*

Results for Hypothesis 4a

Table 4.11shows that significant differences existed between sewing thread brands in relation to seam efficiency both in the warp (*t=-4.023, df=118, p=0.001*) and the weft (*t=-8.202, df=118, p=0.001*) seams. Figure 4.7 indicates that the sewing thread brand B′ had greater seam efficiency than brand A′ in both warp and weft seams.

Results for Hypothesis 5a

With regard to seam elongation, Table 4.11 shows significant differences existed between the two sewing thread brands both in the warp (*t= -2.481, df= 118, p= 0.015*)and weft (*t= -5.400, df= 118, p=0.001*)seams. The mean scores in Table

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4.11and Figure 4.7 show that brand B′ had greater percentage elongations than brand A′ in both the warp and weft seams.

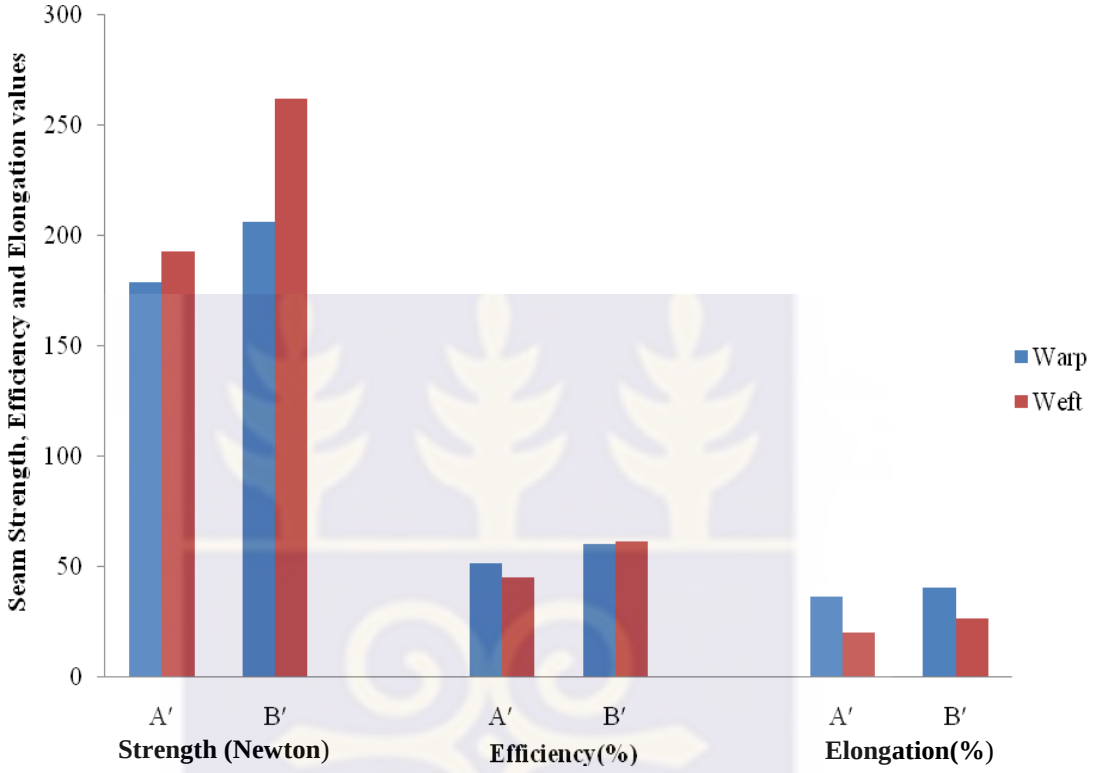


Figure 4.7: Differences between two sewing thread brands with regard to seam strength, efficiency and elongation

4.3.3.2 Testing of Hypotheses 3b, 4b and 5b: *There is no significant difference between stitch densities with regard to 3b) Seam Strength, 4b) Seam Efficiency and 5b) Seam Elongation of A Suitable Fabric for Ghanaian Public Basic Schools Uniforms*

To establish whether significant differences existed between stitch densities in relation to seam strength, efficiency and elongation, hypotheses 3b, 4b, and 5b were

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tested using one-way Analysis of Variance. The result is provided in Table 4.12 (page 151).

Results for Hypothesis 3b

Table 4.12 shows that significant differences existed between the stitch densities used for the study in terms of seam strength in both the warp (*F=28.152, df=2, p=0.001*) and weft (*F=46.452, df=2, p=0.001*) seams. The mean strength values provided in Table 4.12 and Figure 4.8, page 152 indicate that the 14 SPI produced the strongest seams compared to 10 SPI and 12 SPI in both seams (warp and weft). Post Hoc analysis conducted to determine between group variability showed that differences were significant between 14×10 and 14×12 SPIs in the warp seams and 12×10, 14×10 and 14×12 in the weft seams (Table 13, Appendix G).

Table 4.12:Means, Standard Deviations, F-values and *P*-values for seam strength, efficiency and elongation by three stitch densities

SPI / **Parameter**	10		12		14		Df	*F*	*p-value*
	M	SD	M	SD	M	SD			
Strength(Newton)									
Warp	171	32.408	182	23.697	225	42.464	2	28.152	0.001*
Weft	187	33.688	219	34.328	276	54.277	2	46.452	0.001*
Efficiency (%)									
Warp	49	9.570	52	6.306	63	11.389	2	28.396	0.001*
Weft	44	7.844	51	8.921	65	13.742	2	40.813	0.001*
Elongation (%)									
Warp	33	4.691	36	5.133	45	5.665	2	59.885	0.001*
Weft	19	2.198	20	2.388	29	6.576	2	65.110	0.001*

**Significant p<0.05, M=Mean, SD=Standard Deviation*

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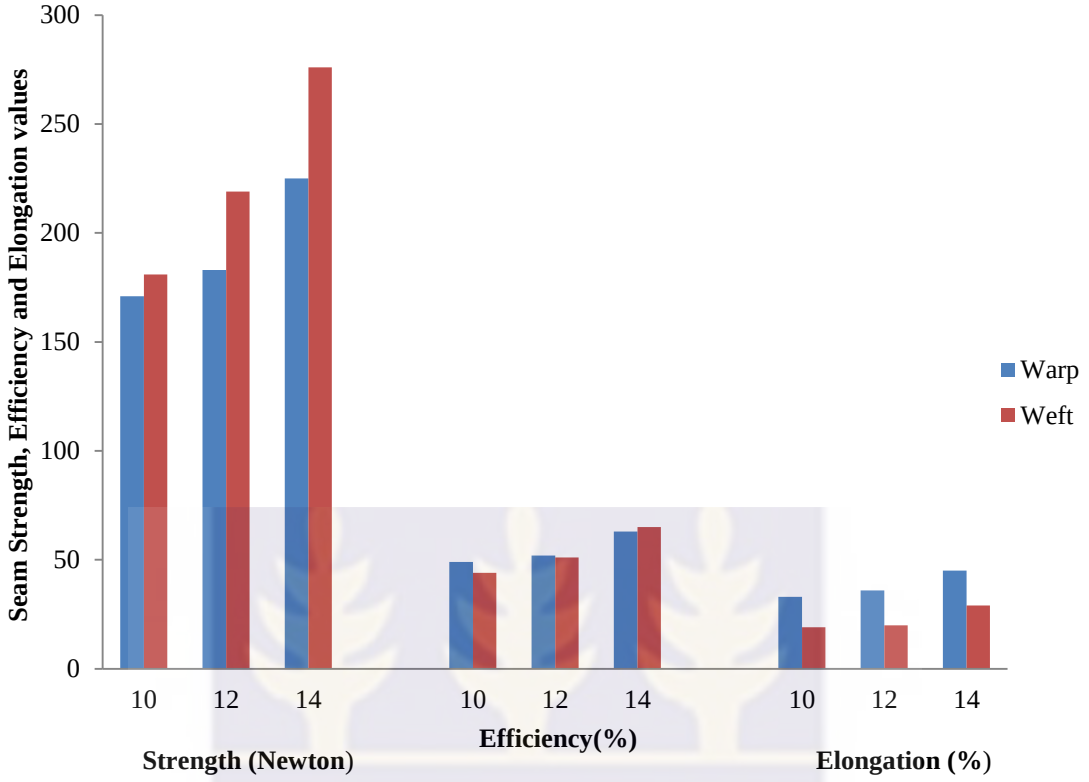


Figure 4.8: Differences between stitch densities with regard to seam strength, efficiency and elongation

Results for Hypothesis 4b

Table 4.12 indicates that significant differences existed between the stitch densities in terms of seam efficiency in both the warp (*F= 28.396, df=2, p=0.001*) and weft (*F=40.813, df=2, p= 0.001*) seams. Figure 4.8illustrates that the 14 SPI had greater percentage efficiency values than the 10 SPI and 12 SPI in both the warp and weft seams. Post Hoc analysis carried out on the data to establish differences between groups, revealed significant differences between 14×10 and 14×12 SPIs for the warp seams and 12×10, 14×10 and 14×12 SPIs for the weft seams (see Table 13, Appendix G).

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Results for Hypothesis 5b

With regard to seam elongation, Table 4.12, page 151, indicates that significant differences existed between the stitch densities both in the warp (*F=59.885, df= 2, p=0.001*) and weft (*F=65.110, df= 2, p=0.001*) seams. Figure 4.8 shows that in both seams (warp and weft), the 14 SPI had highest percentage elongations compared to the 10 and 12 SPIs. Additional analysis to establish differences between groups showed that differences were significant between 14×10 in the warp seams and 14×10 and 14×12 SPIs in the weft seams (Table 13, Appendix G).

4.3.3.3 Testing of Hypotheses 3c, 4c and 5c: *There is no significant difference between wash cycles with regard to 3c) Seam Strength, 4c) Seam Efficiency and 5c) Seam Elongation of A Suitable Fabric for Ghanaian Public Basic Schools Uniforms*

In order to establish whether significant differences existed between wash cycles with regard to seam strength, efficiency and elongation, hypothesis 3c, 4c and 5c, were tested using one-way ANOVA. The results are presented in Table 4.13 (page 155).

Results for Hypothesis 3c

Significant difference was found between the number of times of washing (wash cycle) and seam strength in the warp seams (*F=4.721, df=3, p=0.004*), but not in the weft seams (*F=0.364, df=3, p=0.779*) (Table 4.13). For the weft seams, the mean strength values in Table 4.13 indicate that, seam strength decreased after first wash, decreased after second wash, but increased after 3rd wash. Additional analysis to determine between group differences in the warp seams showed significant

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differences between unwashed and first wash, unwashed and second wash and unwashed and third wash (Table 14, Appendix G).

Figure 4.9, page 156, illustrates the trend of increase or decrease in seam strength as wash cycle progressed. It can be noted that, the warp seams stitched with the two sewing thread brands(A′ and B′)in 10 SPI decreased in strength after 1st wash, but increased in strength after the 2nd and 3rdwashes. Warp seams stitched with sewing thread brand B′ and weft seams stitched with sewing thread brand A′ in 12 SPIs experienced a trend of decrease after each wash cycle (Figure 4.9).The weft seam stitched with thread brand B′ in 14 SPI decreased in strength after first wash, decreased after second wash and increased after the third wash, but had the greatest strength in all the wash cycles (Figure 4.9).

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Table 4.13:Means, Standard Deviations, *F*-values and *P*-values for seam strength, efficiency and elongation by three wash cycles

Parameter / Wash Cycle	Unwashed		1st Wash		2nd Wash		3rd Wash		df	*F*	*p-value*
	M	SD	M	SD	M	SD	M	SD			
Strength (Newton)											
Warp	215	44.531	181	35.688	187	40.392	188	34.269	3	4.721	0.004*
Weft	233	64.904	229	48.941	218	58.243	229	50.703	3	0.364	0.779
Efficiency (%)											
Warp	58	12.167	51	10.215	52	11.191	57	10.356	3	2.920	0.037*
Weft	58	16.229	49	10.425	51	13.699	54	12.014	3	2.703	0.049*
Elongation (%)											
Warp	34	5.393	38	6.574	41	9.095	39	6.479	3	4.311	0.004*
Weft	23	6.874	23	6.323	23	5.399	23	6.026	3	0.031	0.993

**Significant p<0.05, M=Mean, SD=Standard deviation*

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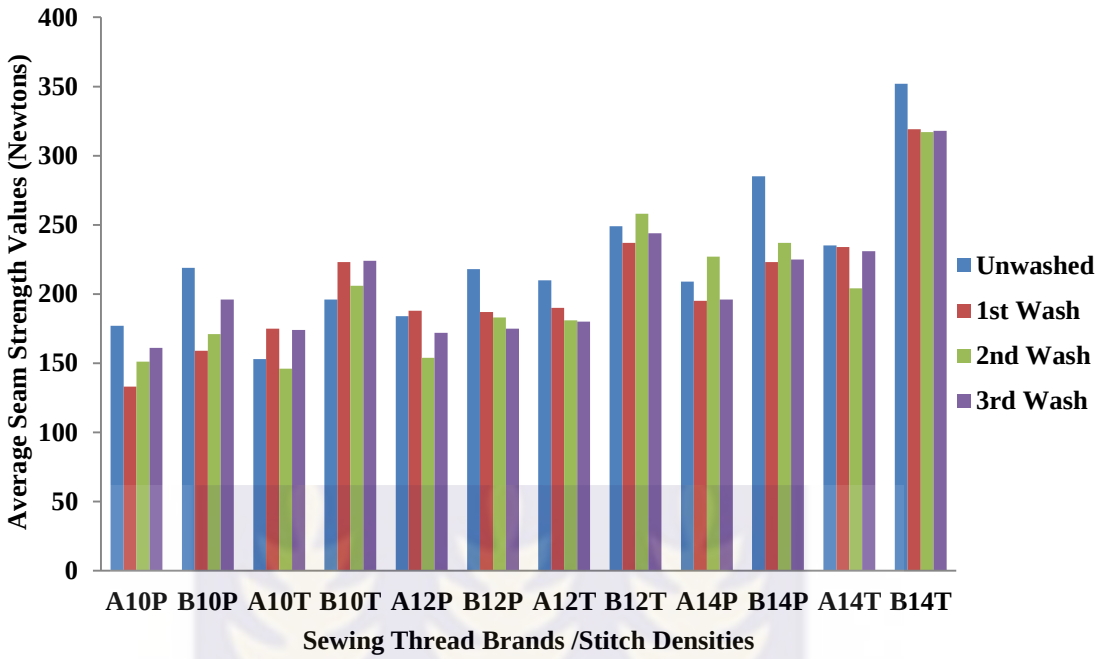


Figure 4.9: Differences between wash cycles in terms of seam strength

Results for Hypothesis 4c

With regard to seam efficiency, significant difference was established between the number of times of washing (wash cycle) in the warp seams (*F=2.920, df= 3, p= 0.037*) as well as in the weft seams (*F=2.703, df=3, p=0.049*) (Table 4.13). From Table 4.13, it can be noted that on the average seam efficiency decreased after the first wash, increased after second wash and increased again after the third wash in both warp and weft seams. Further investigations to determine between group differences indicated that seams in the weft direction had significant differences between unwashed and first wash only (Table 14, Appendix G).

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Figure 4.10illustrates the trend of increase or decrease in seam efficiency as wash cycle progressed. It can be seen that the warp seams stitched with sewing thread brands A′ and B′ and weft seams stitched with sewing thread brand B′ in 10 SPI as well as weft seams stitched with sewing thread brand A′ in 12 SPI, decreased in efficiency after 1st wash, decreased after 2nd wash, but increased after 3rdwash (Figure 4.10). Warp seams stitched with sewing thread brand B′ in 12 SPI and weft seams stitched with sewing thread brand A′ in 10 SPI experienced a trend of decrease after the first and second washes, but increased after the third wash cycle (Figure 4.10).Seams stitched with sewing thread brand B′ in 14 SPI both in the warp and weft had a trend of decrease, increase, and increase after each of the wash cycles, but obtained the greatest percentage efficiency values among their direction of seams throughout the wash cycles (Figure 4.10).



Figure 4.10: Differences between wash cycles in terms of seam efficiency

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Results for Hypothesis 5c

Table 4.13, page 155, indicates that significant differences existed between the number of times of washing and elongation in warp (*F=4.311, df= 3, p=0.004*) seams and not weft seams (*F=0.031, df= 3, p=0.993*).The mean values in Table 4.13 show that the weft seams maintained their elongation throughout the wash cycles. Further analysis of the data to determine between group differences in the warp seams revealed that differences were significant between 2nd wash and unwashed specimens only (Table 14, Appendix G).

Figure 4.11, page 159, shows that warp and weft seams stitched with sewing thread brand A′ in 10 SPI decreased in elongation after the first wash, increased after second wash, but reduced after third wash. Warp seams in 10 SPI stitched with brand B′ sewing thread increased in elongation throughout the wash cycles (Figure 4.11). Weft seams in 12 SPI stitched with brand B′ sewing thread increased in elongation after the first wash but maintained the same level after second and third washes (Figure 4.11). Warp seams stitched with the two brands of sewing threads (A′ and B′) in 14 SPIs experienced a trend of increase, increase and decrease after each wash cycle (Figure 4.11). The warp seam stitched with sewing thread brand B′ in 14 SPI however, had the highest percentage elongations throughout the wash cycles followed by the warp seams stitched with brand A′ sewing thread in 14 SPI (Figure 4.11).

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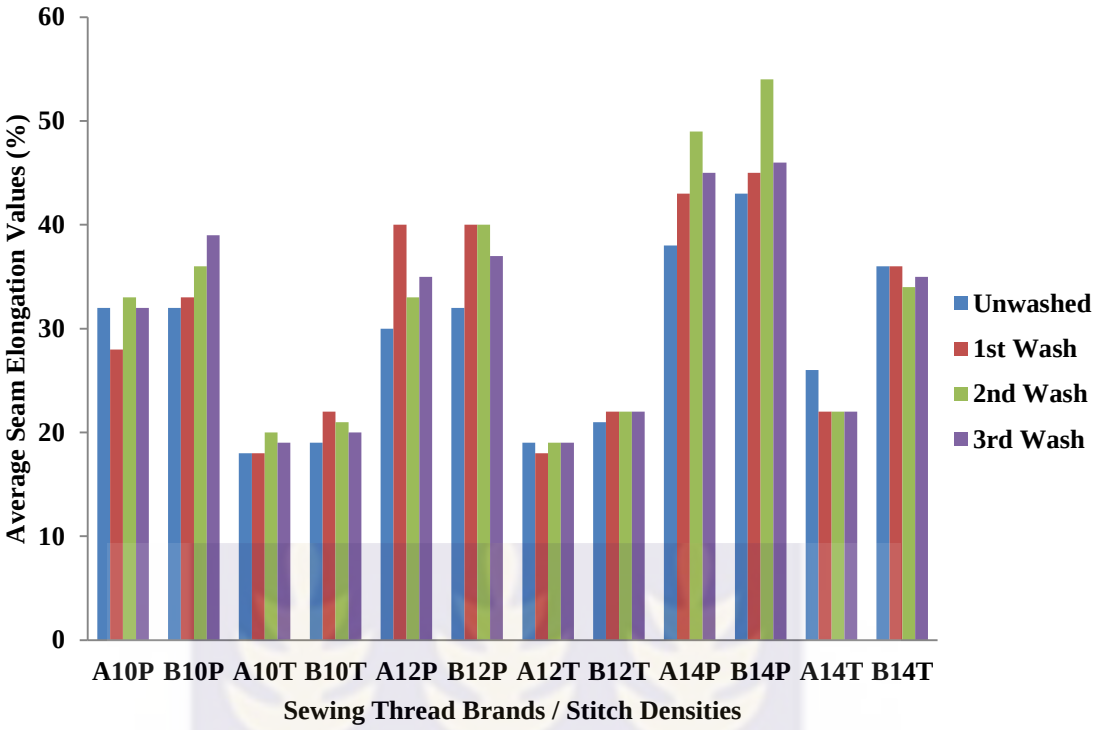


Figure 4.11: Differences between wash cycles in terms of seam elongation

4.3.4 Testing of Hypotheses 6 (a, b, c): *Sewing thread brands, stitch density and washing cycle have no significant influence on the a)Seam Strength, B) Elongation and C) Efficiency of a Suitable Fabric for Ghanaian Public Basic Schools Uniforms*

A 3-Way Analysis of Variance was used to test hypotheses 6 a, b and c and the results are provided in Table 4.14, page 161.

Results for Hypothesis 6a

Table 4.14shows no significant influence of sewing thread brands, stitch densities and wash cycles on the strength of seams in the warp ($p=0.552$) and weft ($p=0.279$) directions. However, Table 15 (Appendix H), shows that the interaction of stitch

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densities and wash cycles have significant influence on the strength of seams in the warp (*p=0.033*) and weft (*p=0.001*) directions.

Results for Hypothesis 6b

Table 4.14 indicates that thread brands, stitch densities and wash cycles had no significant influence on the elongation of seams both in the warp (*p=0.253*) and weft (*p=0.925*). However, Table 15 (Appendix H) indicate significant influence of the interaction of stitch densities and wash cycles on seam elongation in the warp (*p=0.001*) and weft (*p=0.040*) directions.

Results for Hypothesis 6c

The results presented in Table 4.14shows no significant influence of the three independent variables combined on the dependent variable, seam efficiency both in the warp (*p=0.621*) and weft (*p=0.153*). Table 15 (see Appendix H)however, shows significant influence of the interaction of stitch densities and wash cycles on seam efficiency both in the warp (*p=0.034*) and weft (*p=0.001*).

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Table 4.14: 3-Way Analysis of Variance on the Influence of thread brand × stitch density × wash cycle on seam strength, elongation and efficiency

Source	Type III Sum of Squares	df	Mean Square	*F*	*p*-value
Strength **Warp** Thread brand, stitch density and wash cycle	3507.237	6	584.540	0.826	0.552
Weft Thread brand, stitch density and wash cycle	2314.971	6	385.828	1.269	0.279
Elongation **Warp** Thread brand, stitch density and wash cycle	119.413	6	19.902	1.325	0.253
Weft Thread brand, stitch density and wash cycle	9.640	6	1.607	0.319	0.925
Efficiency **Warp** Thread brand, stitch density and wash cycle	258.843	6	43.140	0.737	0.621
Weft Thread brand, stitch density and wash cycle	165.002	6	27.500	1.610	0.153

Strength, *Warp- R Squared= .656 (Adjusted R Squared= .573), Weft- R Squared=.921 (Adjusted R Squared= .902).* ***Elongation****, Warp- R Squared= .773 (Adjusted R Squared= .719), Weft- R Squared=.891 (Adjusted R Squared= .865).* ***Efficiency,*** *Warp- R Squared= .629 (Adjusted R Squared= .540), Weft- R Squared=.925 (Adjusted R Squared= .907), *Significant p<0.05.*

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4.4 Discussion of Results

4.4.1 Discussion for Phase One: Fabric Performance Evaluation

4.4.1.1 Discussion of Results on the Performance Properties of the Fabrics

Weave type and Weight of the Fabrics

All the fabrics studied were plain weave of 1×1 repeat in both warp and weft directions. Differences were observed from Table 4.1, page 126, with regard to the fabrics weight. This finding could be attributed to the different fibre contents, number of yarns in the warp and weft directions and their yarn linear densities. Pizzuto (2012) and Glock and Kunz (2005) indicated that fabric weights vary due to differences in fibre content, number of yarns per 2.5cm (1 inch) as well as in yarn size.

The weights of fabrics B1, B2 and C1 however, fell within the range provided by Pizzuto (2012) for medium weight fabrics which is 120-170 g/m^2 (Table 2.4, page 65), making the fabrics of medium weight. The weights of fabrics A1 and A2 rather fell a little above the higher limit for medium weights and that of C2 fell below the lower limit for medium weigh fabrics and that of C2 below the lower limit for medium weight cloth. Fabrics A1 and A2 are not heavy weight fabrics as their weights are closer to medium than heavy weight ones. Likewise, the weight of C1 is nearer to medium than light weight fabrics. From the results, it can therefore be concluded that all the fabrics used for the study were medium weight and met the standard requirement for weight indicated in the GS 970 (2009).

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Fibre Content of the Fabrics

The fabrics had varying fibre contents. Even within the same brand of fabric, there were variations in the percentage of fibre contents, an example is the observation made with Brand B (Table 4.1). However, the two colours in brand A had the same percentage of fibre contents. From Table 4.1, it is evident that all the fabric brands contained polyester and cellulose (viscose and cotton) with the percentage of polyester being higher in all the brands. For brand C, a look at the fibre content percentage indicates that the fabric is almost 100% polyester.

Yarn Count, Strength and Elongation of the Fabrics

The warp directions of the fabrics had higher number of yarns per inch than the weft (Table 4.1). Similarly, in terms of strength, the warp directions of all the fabrics were stronger than the weft. However, regarding fabric elongation, the weft directions extended more than the warp directions. These findings confirm the general accepted idea that the warp direction of fabrics is stronger than the weft and weft yarns stretch more than warp yarns. The finding on breaking strength is similar to what Ünal et al. (2011) found in the study on analysis and improvement of trouser fabrics used for primary school uniforms that strength in the warp direction of the fabrics they studied was higher than the weft.

The higher strength values obtained in the warp direction than the weft of the fabrics used for the current study, may be due to the higher number of yarns found in the warp than the weft. Mastiekaitè et al. (2013) indicated that, the tensile strength in the warp direction of fabrics is greater than the weft due to higher number of yarns in the warp direction as well as warp yarns usually having higher twist which makes them

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able to resist tension. In this study, the differences in the strength of the warp and weft yarns can also be attributed to the variation in the linear density of the two (warp and weft) yarns. As noted in this study, the warp directions which had greater strength values also had higher yarn linear density values than the weft. This indicates that the yarns in the warp directions of the fabrics are thicker than the weft probably resulting in greater strength in the warp direction. From the results, it can therefore be concluded that the greater strength noted in the warp direction of the fabrics was due to the higher number of thick yarns in the warp direction.

Colourfastness to Washing of the Fabrics

As regards colourfastness to washing, from Table 4.1, it is evident that all the fabrics performed excellently with colour change except B1 which obtained a value between very good and excellent. For colour to staining on cotton, fabrics A1, A2, C1 and C2 had a grey scale rating between very good and excellent with B1 and B2 attaining a very good rating. For staining on polyester, fabrics A1 and B2 had a grey scale rating of excellent while B1, C1 and C2 obtained a rating of very good and A2 had a grey scale rating between very good and excellent (Table 4.1). With regard to staining on nylon, it is observed from Table 4.1 that while fabrics A1, A2, B1 and B2 showed an intermediate rating between very good and excellent, fabric C2 had good rating and C1 had an intermediate rating of good and very good. From the results on colourfastness (colour change and staining) it can be deduced that all the uniform fabrics used for the study have good colourfastness to washing and will perform satisfactorily or maintain their colour during use as school uniforms. The colour of the fabrics is not likely to affect other clothing items worn on the body or during washing. Textile Machinery Network (2013) stated that poor colourfastness in garment such as

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school uniforms can affect other clothing items worn or during washing by destroying the items appearance and wearability.

Dimensional Stability to Washing of the Fabrics

With regard to dimensional stability (shrinkage), the results from Table 4.1 reveals that all the uniform fabrics had the same percentage shrinkage in both warp and weft directions. The percentage shrinkage obtained by the fabrics however, shows good dimensional stability indicating that the fabrics have potential to retain their original shape and remain stable during use and care, making them suitable for the end use.

The finding of this study regarding dimensional stability may be as a result of the fibre content of the fabrics, the fabrics being tightly woven and their yarn count. For instance, Pizzuto (2012) stated that a higher thread count means that more threads are fitted within the fabric and this can reduce fabric shrinkage as the yarns will not have much room to shift. For the fibre contents of the fabrics studied, they all contained higher amounts of polyester which is a hydrophobic fibre. According to Pizzuto (2012), hydrophobic fibres such as polyester shrink less when washed than hydrophilic fibres. The reason given to this was that, fibre swelling which is one of the causes of shrinkage occurs very little in hydrophobic fibres.

The Fabrics Absorbency

The absorbency results indicated in Table 4.2, page 129 and Figures 4.1 to 4.3 show that, fabrics A1, A2, B1 and B2 have very good absorbency while C1 and C2 have poor absorbency. It can be inferred from the results that, fabric brand C would not be able to absorb much sweat from the pupils' body which can cause them to feel uncomfortable making them unable to concentrate even in the classroom . As

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indicated by Das et al. (2009), clothing should have good water vapour and liquid moisture transmission property to be able to provide thermo-physiological comfort. The differences found in the absorbency levels of the uniform fabrics studied may be due to the variation in their fibre contents and yarn linear densities. According to Babu et al. (2015), the absorption property of a fabric is dependent on the fibre used for the manufacture of the fabric in addition to the linear density. In a study on the effect of yarn linear density on moisture management characteristics of cotton/polypropylene double layer knitted fabrics, Babu et al. (2015) found that at increased fineness of polypropylene, water absorption time increased, whereas propylene with coarser cotton yarns took a longer time to reach saturation. Similarly, in this current study, it can be noted that the fabrics that have coarser yarns and contained higher amount of cellulose used less time to completely absorb the water drop and yet did not reach saturation. On the other hand, those with the fine yarns and had a greater amount of polyester (C1 and C2) used a longer period yet the drop of water could not be absorbed completely as shown in Figure 4.3, page 130.

4.4.1.2 Comparison of Investigated Fabrics Performance Characteristics with Standard Specifications for Uniform Fabrics

Comparison of Fibre Content, Weave type, Dimensional Stability and Colourfastness to Washing

The fabrics used for the study met the requirement for fibre content indicated in GS 970:2009. The fabrics studied were woven and met the specification of the Ghana Standards Authority for uniform fabrics (Table 4.3, page 131). In terms of dimensional stability (shrinkage), all the fabrics had good dimensional stability and obtained shrinkage values both in the warp and weft that met the standard in GS

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970:2009.With regard to colourfastness (colour change and staining) to washing, all the fabrics had good colourfastness and obtained grey scale values greater than the values indicated in GS 970:2009 (Table 4.1 and 4.3). This might be due to the use of good quality dyes by the manufacturers of all the fabrics investigated. The finding from this study is similar to Ünal et al. (2011). Ünal et al. (2011) found in a study on the analysis and improvement of trouser fabrics for primary school uniforms that colour change values for all the fabrics they investigated were acceptable. However, it is observed that the GS 970:2009 did not indicate any grey scale value for wool, and the polyamides, so no comparison could be made.

Comparison of Weight and Strength of the Fabrics

The weights of the fabrics studied met the standard requirement provided by Ghana Standards Authority for uniform fabrics. The tensile strength of fabrics suitable for uniforms are determined based on their weights as indicated in GS 970:2009. However, the mean weight values presented in Table 4.1 shows that fabric brands B and C had weight values with corresponding strength values in the warp and weft directions greater than the minimum strength values indicated in GS 970:2009for fabrics with such weights. On the other hand, the weight of fabric brand A could not meet the minimum required strength values in both warp and weft directions indicated in GS 970:2009 for fabrics with such weight, indicating non-conformance to standards. In the GS 970:2009, it is stated that a suitable fabric for uniforms should meet all the standard requirements indicated. As the strength of a fabric determines its ability to withstand the forces in use and remain strong for the garments use life, strength requirements for fabrics such as school uniform fabrics for children should be met. Mehta and Bhardwaj (1998) and Ünal et al. (2011) indicated that strength

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properties of garments have traditionally been considered the most obvious indicators of the service life of garments. This shows that if a fabric does not meet strength requirements, it means the fabric is likely to fail early in its use especially in the case of children's school uniform fabrics. In addition, the fabrics investigated are used for garments that are part of the range of products indicated by Pizzuto (2012) as requiring maximum durability because such products are frequently subjected to high stress during wear. The products range stated include utility work wear, uniform clothes and children's play wear. From the results and discussion, it can be stated that fabric brand A might not perform satisfactorily in terms of strength during use as school uniform.

4.4.1.3 *Suggested additions to the GS 970:2009 (Standard Specification For Uniform Fabrics)*

The researcher noted that certain other important parameters that could also help in deciding suitability of fabrics for uniforms were not indicated in the GS 970:2009. The parameters are yarn count, yarn linear density, fabric elongation and absorbency. They are discussed in the sub-headings that follows;

Yarn Count Properties of Fabrics

Yarn count is one parameter that is indicative of quality in fabrics (Pizzuto, 2012). Pizzuto (2012) stated that in most end uses where durability is important such as in children's wear, uniforms and active sportswear, higher ends and picks per inch are preferable to lower counts. This shows that since durability is paramount in uniform fabrics there is the need to provide acceptable numbers of ends and picks per inch at which uniform fabrics can perform satisfactorily. That will aid manufacturers to

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follow suit and come up with variety of fabrics that can be used for such products. Perhaps if other set standards for various end-uses are studied and additional analysis carried out on other fabrics in addition to what has been done in this current study, an estimate of the number of ends and picks per inch can be established for uniform fabrics.

Yarn Linear Density Properties of Fabrics

With regard to yarn linear density, it is established from literature and this current study, that it influences a number of fabric performance properties such as strength, absorption, weight and resiliency. For instance, Saiman et al. (2014) observed that the mechanical properties such as strength, increased when yarn linear density increased. As evident from this current study, the brand C had the highest number of ends and picks per inch yet attained the least weight values (Table 4.1) and performed poorly with regard to absorbency. This can be attributed to its fibre type and the linear density as it had the lowest linear density values both in the warp and weft directions. Even though the linear density of fabric brand C is low, their strength values met the set standard for their weight and this could be due to the kind of fibre it is made of which is polyester. It must however, be noted that looking at its absorbency level, such a fabric is not suitable for the kind of weather in Ghana. The finding shows that yarn count alone cannot be used to judge the quality of a fabric especially in terms of weight, strength and absorbency, but other attributes such as fibre type and linear density must be taken into consideration. There is therefore the need for linear density to be included in the standard specification with the appropriate values for warp and weft directions.

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Elongation Properties of Fabrics

Fabric elongation is another attribute that is required for fabrics to perform satisfactorily which is not indicated in GS 970:2009. Pizzuto (2012) stated that the wear life of a fabric correlates to both fabric strength and elongation. It was further stated that with all other factors being equal a fabric with lower breaking strength, but higher elongation is likely to remain wearable for long period as the elongation helps the fabric to better withstand the forces of normal wear (Pizzuto, 2012). European Apparel and Textile Confederation (EURATEX) Technical Clothing Group (2006) for example, provided range of percentage elongations that fabrics for shirts, dresses and blouses should have as well as trousers, shorts and skirts. For shirts, dresses and blouses the range was from 12.5% to 40% and that of trousers, shorts and skirts was 12.5% to 55%. Comparing the percentage elongation values obtained by all the brands of fabrics used for the study to what EURATEX Technical Clothing Group (2006) indicated for shirts, dresses, blouses, trousers, shorts and skirts, it can be said that they fell within the range. This shows that all the fabrics are acceptable for use as shirts and uniform fabrics in terms of elongation. The comparison was made with the values provided by EURATEX Technical Clothing Group (2006) since is not catered for in the GS 970: 2009. In addition, Masteikaitė et al. (2013) also compared the elongation of the fabrics they studied to the EURATEX Technical Clothing Group (2006) range in their work on the deformability analysis of fabrics used for school uniforms. Perhaps the Ghana Standards Authority need to add the fabric elongation attribute with corresponding values for warp and weft directions to the GS 970:2009 to help manufacturers of shirts and uniform fabrics to have a guide that can aid in producing quality fabrics for the end-use.

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Absorbency Properties of Fabrics

Fabric absorbency as indicated by Pizzuto (2012) influences many conditions of fabric use including skin comfort. Das et al. (2009) added that moisture absorption is one of the key performance measures in today's apparel industry deciding comfort level of fabrics. Yet, this property is not part of the parameters noted in GS 970:2009. If a fabric absorbs little amount of perspiration for example, individuals in garments made from such fabrics will feel very uncomfortable. From this research it has been observed that the fabric brand C will not be able to absorb much sweat from pupils if used for school uniform construction; consequently is likely to cause discomfort in pupils as well as cause them to "Smell" as their sweat and body heat will be retained within the garment causing bad odour. However, the brand C performed well on the other parameters indicated in GS 970:2009. It was therefore the absorbency test that showed that it will not be suitable for school uniforms for children in Ghana.

Ghana is a tropical area characterised by humid and hot weather. In addition children play a lot and therefore perspire enormously; consequently they require garments made from fabrics that have very good absorbency property to enable them feel comfortable in the learning environment. The fibre type of the fabric brand C can be said to be a contributing factor to the absorbency behaviour as well as the yarn linear density. However, it is observed from the GS 970:2009 that the fibre type indicated as required for uniform fabrics is more or less left open without taking cognisance of the weather conditions in Ghana. The fibre type indicated include 100% polyamide, 100% polyester, meaning even 100% nylon fabric that meets all the other requirements indicated in GS 970:2009 will qualify to be used as a uniform fabric. However, Keiser and Garner (2012) indicated that polyester is hydrophobic and not suitable for tropical

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climates unless blended with a cellulosic fibre such as cotton and rayon. They explained that because polyester is hydrophobic instead of absorbing sweat, it allows perspiration to build up inside the garment. Perhaps if absorbency is added to the parameters in GS 970:2009, it would indicate that fabrics like 100% polyester and nylon even though may be strong; will not be comfortable for use as school uniforms in the Ghana.

4.4.1.4 Discussion of Results for Hypotheses 1 (a, b, c, d and e)

The analysis of variance results, Table 4.4, showed significant differences among the weights, strengths, elongations, shrinkage and yarn counts of the fabrics. The finding is not consistent with the null hypotheses and so the null hypotheses were rejected. The differences found among the weights and strengths of the fabrics investigated might be due to the disparity in the fabrics fibre contents, yarn counts as well as their yarn linear densities.

The differences noted among the fabric brands and their breaking elongation is contrary to what Mastiekaitè et al. (2013) found. In a study on the deformability analysis of fabrics used for school uniforms, Mastiekaitè et al. (2013) observed that the degree of elongation at maximum force for the fabrics they tested was not different. Although differences existed among the uniform fabrics percentage elongations, the values they all obtained fell within the range provided by EURATEX Technical Clothing Group (2006) for fabrics for such end-uses. It can therefore be said that all the fabrics employed for the study will perform well in terms of elongation in use.

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For dimensional stability (shrinkage), although, disparity existed among the fabrics studied, they all met the standard requirements indicated in GS 970:2009. This indicates that all the fabrics studied will do well during use with regard to dimensional stability. With regard to the yarn counts of the fabrics, Figure 4.4, page 135, illustrates that even within the same brand there existed slight differences in yarn counts of the fabrics in both warp and weft directions. The results for yarn count is consistent with Ünal et al. (2011) who also found differences in the yarn counts of the trouser fabrics used for primary school uniforms they investigated.

4.4.1.5 Discussion of results for Hypotheses 2(a, b, c and d) and *Differences between Wash Cycles and the Colourfastness of the Fabrics*

Hypothesis 2a

The analysis of variance results, Table 4.5, indicate significant differences among the number of times of washing and the investigated fabrics strengths both in the warp and weft directions. This result was not consistent with the null hypothesis; therefore the null hypothesis was rejected. The result in this study proves that washing cycles have effect on the strengths of fabrics. As evident from Figure 4.5, page 138, there is a trend of increase and decrease after each wash cycle in each of the fabrics studied. For instance, the fabric B1 in the weft direction experienced decrease in strength with increase in the number of times of washing where the least strength occurred after the third washing, but still met the standard requirement for strength indicated in GS 970:2009. Fianu, Sallah and Ayertey (2005) observed that the laundered specimens from the wax print fabric they used for their study, experienced much loss in strength. Their finding is similar to what is observed in this current study.

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Hypothesis 2b and 2c

The results presented in Table 4.5 showed significant differences existed among the number of times of washing and fabric elongation in the warp direction, but not the weft. The result from the warp direction was not consistent with the null hypothesis so the null hypothesis was rejected. On the other hand, that of the weft was consistent with the null hypothesis so the researcher failed to reject the null hypothesis.

In terms of differences among the number of times of washing and the fabrics weights (hypothesis 2c), no significant difference was found. The researcher therefore failed to reject the null hypothesis. Research works on the effect of washing cycles on the elongations as well as weights of fabrics seem non-existent so no comparison could be made. However, as evident from this study, washing cycle affected the elongations of the fabrics in the warp direction showing that if further analyses are done on the same fabrics the trend of washing cycle influence could be better established. For instance, Figure 4.6, page 139, illustrates that each brand of fabric experienced an increase and decrease trend in elongation after each wash cycle.

Hypothesis 2d

With regard to differences among the number of times of washing and the fabrics dimensional stability (shrinkage)(Table 4.5),no significant differences were found so the null hypothesis was retained. The finding is however, contrary to Toshikj and Mangovska (2011) finding that repeated laundering affected shrinkage regardless of the detergent and grade of cotton fabric. This was established in their work on the effect of laundering of cotton knitted fabrics with different detergents on dimensional stability and colourfastness. The differences in their findings and that of the current

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study may be due to the variation in the structure of fabrics used. The current study used woven fabric structures, but in their work knitted fabrics were used. In addition, Anand et al. (2002) discovered changes in the dimensions of the fabric they studied due to laundering, which is also at variance with what is found in the current study.

Differences between Wash Cycles and the Colourfastness of the Fabrics

With regard to differences among the number of times of washing and colour change of the fabrics studied, the results in Table 4.6 indicate that while fabrics A1, A2, B2, C1 and C2 showed an excellent rating on the grey scale, fabric B1 had an intermediate rating between very good and excellent after the first wash. Interestingly, after the second wash, all the investigated fabrics attained an intermediate rating between very good and excellent. This shows that fabrics A1, A2, B2, C1 and C2 dropped from excellent to intermediate rating between very good and excellent after the second wash. After the third wash, while fabrics A2, B2, C1 and C2 maintained their intermediate rating between very good and excellent after the second wash, fabrics A1 and B1 dropped to have a grey scale rating of very good. In general, it was observed that minimal differences existed between the number of times of washing and the colour change of the uniform fabrics investigated. This finding is similar to what Lawal and Nnadiwa (2014) found when they evaluated wash and light fastness of some selected printed fabrics. They observed marginal differences between wash and light fastness of the fabrics they studied. The grey scale values obtained by the fabrics studied in all the wash cycles with regard to the current study, however, are acceptable and indicate that all the fabrics will perform well in terms of colourfastness during use. The finding is similar to what Toshikj and Mangovska (2011) found.

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Toshikj and Mangovska (2011) found that the knitted fabrics they studied had excellent colourfastness to washing.

As regards the staining properties of the fabrics investigated, the results in Table 4.7 indicate that there was a minimal amount of staining on the undyed multi-fibre fabric attached to the specimens before washing. It is however, noted that after the first wash fabrics C1 and C2 were the only fabrics that had an intermediate rating between good and very good relating to staining on nylon. For staining on acetate, brand C again attained a good rating on the grey scale after the first wash. In addition, brand A obtained an intermediate grey scale rating between good and very good with regard to staining on acetate after the first wash. It was observed that after the third wash almost all the uniform fabrics used for the investigations attained a grey scale rating of excellent, showing no contrast. Generally, not much difference existed between the number of times of washing and the staining properties of the uniform fabrics studied. All the fabrics had acceptable staining values on the fibres indicated on the multi-fibre fabrics, showing that they will perform satisfactorily in terms of staining during use. This outcome is similar to what was noted by Ünal et al. (2011) that staining properties of the uniform fabrics they studied were very good.

In a nutshell, from the results of all the parameters studied, the fabric brand B was noted to perform very well and is recommended as suitable for school uniforms.

The brand B met the requirements for the parameters stated in GS 970:2009 and its elongation and absorbency properties were very good. For instance, throughout the wash cycles, the strength values of brand B were above the standard requirements set in the GS 970:2009. Fabric B2 was selected for the phase two of the study. Fabric

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brand A was not chosen as it did not meet the minimum requirements for strength in the GS 970:2009. Fabric brand C was also not selected due to its poor absorbency. Children are very active and their activities involve a lot of play hence they sweat profusely especially in the tropics. This requires that their garments are washed frequently. They therefore require garments from fabrics that are strong and absorbent. Good absorbency will make them feel more comfortable in their uniform garments as they carry out their activities. In addition, a fabric which did not meet the minimum strength requirements for such an end use (uniform) is likely to fail at the early stages of use as washing was noted to have influence on the strength and elongations of the fabrics studied.

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4.4.2 Discussion for Phase Two: Seam Performance Evaluation

In this study one type of deformation was observed in all the specimens used for the seam performance evaluation which was rupture of the stitching line.

4.4.2.1 Discussion on the Performance Characteristics of Fabric and Sewing Threads

The results presented in Table 4.8, page 143, show that the fabric was medium weight. The number of yarns in the warp direction of the fabric was more than the weft. The linear density of the fabric was higher in the warp direction than the weft. This indicates that the yarns in the warp direction of that fabric were thicker than those in the weft direction. It can be seen from Table 4.8 that the fabric used for seam performance evaluation, was stronger in the warp direction than weft, but for fabric elongation, the weft direction was higher than warp. This result verifies the commonly accepted notion that the warp direction of fabrics are stronger, but stretch less compared to the weft. The higher strength value observed in the warp direction of the fabric can be attributed to the greater number of yarns in the warp direction of the fabric as well as the thicker yarns used in that direction as observed in the linear density values.

The sewing thread brands used for the study were both 100% polyester, but brand B′ (M= 44tex) had a higher linear density value compared to brand A′ (M= 30tex) (Table 4.8). From the linear density values of the two threads, it can be inferred that brand B′ was thicker than brand A′.

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4.4.2.2 Discussion on Differences between Fabric Tensile Properties (Strength and Elongation) and Seam Tensile Properties (Strength and Elongation)

Differences between Fabric Strength and Seam Strength

To establish differences between fabric strength and seam strength, fabric strength in the warp direction is compared to weft seam strength. This is because when seams are made parallel to the weft direction; force is applied on the warp yarns of the fabric. Same applies to the opposite direction and that of elongation.

Descriptive statistics, Table 4.9, page 145, shows differences between the fabric strength and seam strength in both the warp and weft directions throughout the wash cycles. Interestingly, the fabric was stronger than the seams all through the wash cycles. The findings substantiate previous findings in the literature indicated by Bharani and Gowda (2012) that the force required to break the seam is usually less than that required to break the un-sewn fabric. The result is consistent with what Chowdhary and Poynor (2006) found. In a study on the impact of stitch density on seam strength, elongation and efficiency, Chowdhary and Poynor (2006) observed that, the fabric they used for their study was stronger than the seams in both warp and weft directions for all the three stitch densities they employed for their study.

Differences between Fabric Elongation and Seam Elongation

With regard to elongation, differences were found between the fabric and the seams (Table 4.10, page 147). It was noted, for example, that warp seams stitched with sewing thread brand B′ in 14 SPI had higher percentage elongations than the fabric throughout the wash cycles. This phenomenon could be attributed to the sewing

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thread brand and increase in stitch density. As stitch density increases more thread moves into the sewn fabric making the stitch able to stretch more than when the stitch density is low. In addition, if the sewing thread has a superior elongation, it will add to the elongation of the seam. The finding is consistent with what ASTM D6193-09 (2009), Barbulov-Popov, et al. (2012) and Mehta and Bhardwaj (1998) indicated. They noted that the elongation of a sewn seam is supposed to be slightly higher than the fabric which it joins, to enable the fabric to support the forces encountered by the garment in use. This shows that the results from the seams stitched with the 14 SPI in the two threads especially thread B′ is acceptable. However, the result is contrary to what Chowdhary and Poynor (2006) and Kadolph and Langford (2002) found. They noted higher percentage elongations for seams than the fabrics they used for their investigations. For Chowdhary and Poynor (2006), they observed that seams had higher elongations than the fabric in both warp and weft directions for all stitch densities. The differences established between the findings of previous studies and this current study relating to fabric and seam elongation may probably be due to differences in the fabrics and sewing threads used for the investigations. Chowdhary and Poynor (2006), for instance, used 100% cotton muslin for their study and in the current work the fabric employed had a higher percentage of polyester (79%) than cotton (21%). ASTM D6193-09 (2009), Barbulov-Popov, et al. (2012) and Mehta and Bhardwaj (1998) indicated that seam elongation is dependent upon factors such as fabric type and stitch density. As observed in this study, in general the seams with the highest elongations had the highest level of stitch density.

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4.4.2.3 Discussion of Results for Hypotheses 3a, 4a and 5a

Independent samples *t-test*, Table 4.11, revealed that the differences for seam strength, efficiency and elongation were significant for the two sewing thread brands both in the warp and weft directions. The null hypotheses which state that there is no significant difference between sewing thread brands with regard to seam strength, efficiency and elongation in a suitable fabric for Ghanaian public basic school uniforms were rejected. Figure 4.7illustrates that on the average, the brand B′ sewing thread produced greater seam strength, efficiency and elongation than brand A′. It can be deduced from this finding that the brand B′ thread is likely to produce higher seam strength, efficiency and elongation in the uniform fabric used for the study than brand A′.

Hypothesis 3a

The variation in the seam strength values of the two sewing thread brands could be attributed to the differences in their linear density values. American and Efird Inc. (2009) indicated that given a specific fibre type and thread construction, the larger the thread size, the greater the seam strength. Gribaa et al. (2006) also stated that, the finess of thread affects the strength of seam, with thicker threads providing a better seam strength. From the linear density values of the two threads, it can be inferred that thread B′ (44tex) is a thicker thread compared to thread A′ (30tex) (Table 4.8). Sewing thread brand B′ can be said to be stronger than A′ as it produced seam strengths greater than A′. Mehta and Bhardwaj (1998) indicated that stronger sewing threads give stronger seams. The result is consistent with what Mukhopadhay (2008) and Choudhary and Goel (2013) found. They observed increase in seam strength with increase in linear density of sewing thread. Although Mukhopadhay (2008) worked

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with chain stitched seam, same has been observed with the lock stitch seam in the current study. The result also confirms previous research finding by Barbulov-Popov et al. (2012) that sewing thread linear density used for a particular assembly have great influence on defining seam strength. Similar to the finding of this study, Danquah (2010) and Akter and Khan (2015) also observed differences in sewing thread types with regard to seam strength.

Hypothesis 4a

The disparity in the efficiency values produced by the two brands of threads might be due to the differences in their sizes. The brand B′ was noted to be thicker than A′. According to Bharani and Gowda (2012), Choudhary and Goel (2013) and Sarhan (2013), sewing thread size is critical for seam quality and poor choice directly affects seam performance properties in garments. Sarhan (2013) verified the effect of sewing thread linear density on seam performance. He noted increase in seam efficiency as sewing thread linear density increased which is also evident in this current study. The percentage efficiency values provided by the two threads are less than 100% confirming the earlier results in Table 4.9 that the fabric is stronger than all the seams stitched with the two thread brands in the three stitch densities. Chowdhary and Poynor (2006) asserted that percentage efficiency more than 100% means the seam is stronger than the fabric and the reverse means the fabric is stronger. In situations where the fabric is stronger than the seam as observed in this study, when pressure is applied at the seam, the stitch line will break instead of the fabric, making it easy to repair and still maintain the original shape and style of the school uniform. Stamper et al. (1991) pointed out that if a seam in a garment is stronger than the fabric it joins,

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undue stress can cause the fabric to split at the seam making it difficult to repair such damage and still maintain the garments' original size and beauty.

The seam efficiency produced from the two threads ranged from 40% to 62%. However, the seam efficiencies obtained by thread B′ ranged from 60-62%. Mehta and Bhardwaj (1998) noted that seam efficiency of about 60-70% indicates that the seam will be commercially acceptable and will perform satisfactorily in use. It can be noted that the upper limit of 62% found with the threads used for the study and the efficiencies obtained by the sewing thread brand B′ fell within the range. Indicating the seams from brand B′ sewing thread will perform satisfactorily in use. Chowdhary and Poynor (2006) pointed out that Mirafi's report noted a range between 40% and 60% for typical seam efficiencies within which the efficiency values from the two threads used for the study fell. In addition, Mirafi's report in Chowdhary and Poynor (2006) indicated seam efficiency of a medium-weight fabric stitched with polyester threads ranges from 40% to 50%. The school uniform fabric used for the current work weighed 138g/m^{2}which qualify it as a medium weight fabric and the sewing threads were both 100% polyester. This shows that the seam efficiencies produced by the two thread brands in this current study met the usual range for seam efficiencies.

Hypothesis 5a

In a study on the impact of laundering on seam tensile properties of suiting fabrics, Mukhopadhyay et al. (2004) found increase in seam elongation with yarn thickness with elongation being higher in the coarser yarn as observed in the current study.

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4.4.2.4 Discussion of Results for Hypotheses 3b, 4b and 5b

Analysis of variance revealed that the differences for seam strength, efficiency and elongation were significant for the three stitch densities in both warp and weft directions (Table 4.12). The null hypotheses were rejected. The 14 SPI had the highest values for strength, efficiency and elongation (Figure 4.8). This means that the 14 SPI if used to construct seams in the school uniform fabric employed for the study, will produce better seam strength, efficiency and elongation than the 10 and 12 SPIs. It was observed that seam strength, efficiency and elongation increased with increase in stitch density(Figure 4.8).

In terms of seam strength, the finding confirms the assertion by American and Efird Inc. (2010) and Mehta and Bhardwaj (1998) that in general the more stitches per inch the greater the seam strength. AMANN Inc. (2009) noted that increasing stitch density by only one stitch per centimetre, leads to 25-30% increase of seam breaking strength. Nassif (2013), for instance observed 17% increase in seam strength with increase in stitch density. The finding of this current study is consistent with American and Efird Inc. (2010), Danquah (2010) and Chowdhary and Poynor (2006) finding. They all found increase in seam strength as stitch density increased. Chowdhary and Poynor observed significant differences for seam strength for three stitch densities in both warp and filling directions as seen in this current study.

With regard to seam efficiency, the result is similar to what Chowdhary and Poynor (2006) and Nassif (2013) found. They noted increase in seam efficiency with increase in stitch density with Nassif (2013) detecting 16% increase. The efficiency values produced by the three SPIs used for the study, ranged between 40% and 66% with the

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14 SPI ranging between 60 to 66%. The efficiency values given by the three SPIs is consistent with the typical seam efficiency range of 40% and 60% stated by Chowdhary and Poynor (2006). The efficiency of the 14 SPI fell within the range indicted by Mehta and Bhardwaj (1998) as required for seams to be commercially acceptable which is 60-70%. In addition, the seam efficiency values indicate that the fabric was stronger than all the seams stitched in the three SPIs employed for the study.

For seam elongation, the results is consistent with Chowdhary and Poynor (2006) who noted differences in seam elongation and three stitch densities in both the warp and filling directions of the fabric they employed for their work. Nassif (2013) also found increase in seam elongation with increase in stitch density same as noted in this current study.

4.4.2.5 Discussion of Results for Hypotheses 3c, 4c and 5c

Analysis of variance showed no significance difference for the number of times of washing with regard to seam strength and elongation in the weft seams (Table 4.13, page 155). On the other hand, significant differences were observed for number of times of washing in terms of seam strength and elongation in the warp seams (Table 4.13). As regards seam efficiency, there was evidence of significant differences between the number of times of washing in both the warp and weft seams(Table 4.13). The results in the weft seams for seam strength and elongation confirmed the null hypotheses; therefore the researcher failed to reject the null hypotheses. However, the results from the warp seams regarding seam strength and elongation and the warp

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and weft seams for seam efficiency were not consistent with the null hypotheses so the null hypotheses were rejected.

Hypothesis 3c

The finding in the warp seams regarding seam strength is consistent with what Mukhopadhyay et al. (2004) found. In their study on the impact of laundering on the seam tensile properties of suiting fabric, they observed that the effects of laundering on seam tensile properties of suiting fabric were significant. In addition, the result is similar to Babu et al. (2009). Babu et al. (2009) found that the warp-way seams had distinct increase in strength with increase in the number of washes, but the weft–way seams showed marginal increase with increase in the number of washes. Figure 4.9shows the trend of increase or decrease in seam strength as wash cycle progressed with the seams stitched with the two thread brands (A′ and B′) in the three SPIs (10, 12 and 14). It can be noted that weft seams stitched with brand B′ in 14 SPI had the highest strength values throughout the wash cycles. On the whole, it can be stated that, looking at Figure 4.9 differences did exist between the number of times of washing and seam strength of all the seams stitched with the two thread brands in the three SPIs. Mukhopadhyay et al. (2004) found reduction in seam strength as a result of laundering with the reduction being greater for coarser sewing threads, but same cannot be said in this current study due to the trend of increase or decrease seen in the sewing threads. Mukhopadhyay (2008) also noted that force at break increased on laundering with the change occurring more in seams stitched with coarser sewing thread. In this current work, Figure 4.9 reveals that the brand A′ which is deduced from its linear density value as being a fine thread had increase in strength after the third washing in most of the seams. This is contrary to Mukhopadhyay (2008).

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Hypothesis 4c

For seam efficiency, Table 4.13 shows that seam efficiency varied in both directions as wash cycle progressed with the unwashed specimens in both directions having the greatest percentage efficiencies followed by third wash in both directions. The finding is similar to Shawky (2013) who found significant effect of laundering on seam efficiency. The seam efficiency values obtained from the wash cycles ranged from 40% to 59% indicating that the fabric was stronger than the seams after each wash cycle as observed in Table 4.9. The current result is somewhat dissimilar to what Babu et al. (2009) observed that seam efficiency reduced with increase in the number of washes. This is stated because Figure 4.10 portray that seam efficiency after third washing increased for all seams in both sewing thread brands and SPIs in both directions except for the seams stitched with brand B′ in 12 SPI and brand A′ in 14 SPI in the weft direction. Another observation made from Figure 4.10 is that amongst the weft seams, the ones stitched with thread brand B′ had high percentage efficiencies throughout the wash cycles. Surprisingly, the weft seam stitched with brand B′ sewing thread in 14 SPI obtained the highest seam efficiency throughout the wash cycles compared to all the other seams in both warp and weft directions. For the warp seams, the one stitched with sewing thread brand B′ in 14′ SPI gained the highest seam efficiency values throughout the wash cycles. In all, the seams in the thread brand B′ especially those in the 14 SPI performed well with regard to seam efficiency throughout the wash cycles (Figure 4.10). This shows that when the thread brand B′ with the 14 SPI is used in making seams in the suitable school uniform fabric, it would perform satisfactorily during use and care.

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Hypothesis 5c

With regard to seam elongation, it can be seen from the mean scores in Table 4.13 that in the warp seams, elongation increased after first and second washes and decreased after the third wash. For the weft seams, elongation was maintained throughout the wash cycles. Shawky (2013) found that laundering had significant effect on seam elongation which is similar to the findings of this study in the warp direction. In addition, Figure 4.11illustrates that there were variations in the number of times of washing with regard to seam elongation. For instance, warp seam stitched with sewing thread brand B′ in 10 SPI experienced increase in seam elongation throughout the wash cycle. In general, from Figure 4.11, the weft seams stitched with thread brand A′ in 10 and 12 SPIs had the lowest percentage elongations all through the wash cycles.

Figure 4.11shows that weft seam stitched with thread brand B′ in 14 SPI had the highest percentage elongations all through the wash cycles compared to other weft seams; it is followed by seam stitched with thread A′ in 14 SPI then B′ in 12 SPI and B′ in 10 SPI. Interestingly, the warp seam stitched with sewing thread brand B′ in 14 SPI obtained the highest elongation values in all the wash cycles compared to all the other seams. Generally, seams in the brand B′ thread performed well in terms of seam elongation in all the wash cycles (Figure 4.11). Seam elongation for warp seams throughout the wash cycles seemed higher than the weft seams (Figure 4.11). The trend may be due to the direction of the fabric where force is applied for each seam. For the warp seams, they are parallel to the warp yarns of the fabric and so the force is applied on the weft yarns of the fabric which are known to stretch more compared to warp yarns. This proves the generally accepted idea that weft yarns stretch more than

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warp yarns as it shows that the fabric elongation also contributes to the seams' elongation.

4.4.2.6 Discussion of Results for Hypotheses 6 (a, b and c)

The 3-way analysis of variance results, Table 4.14, show that the three independent variables (sewing thread brand, stitch density and wash cycle) combined had no significant influence on seam strength, elongation and efficiency in both directions of the fabric used for the study. The finding was consistent with the null hypotheses and therefore the researcher failed to reject the null hypotheses. The result is dissimilar to what Mukhopadhay et al. (2004) found. They observed that the effect of stitch density, count of sewing threads, fabric composition and laundering on seam tensile properties of suiting fabric were very significant.

The finding is contrary to Danquah (2010) who found significant influence of sewing thread type, stitch density and washing cycle on seam strength and elongation in the warp direction and seam efficiency in the weft direction. The differences in the findings could probably be due to differences in the fabric and other sewing parameters (e. g. sewing thread brand, stitch density) used for the investigations in Mukhopadhay et al. (2004) and Danquah (2010). For instance, in the view of Choudhary and Goel (2013) and Bharani and Gowda (2012) differences in fabric properties that can affect seam quality include weight, strength, shrinkage and extensibility.

Although the three independent variables combined had no significant influence on the seam performance properties evaluated, the results from the output from the 3-way

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ANOVA presented in Table 15 (Appendix H) indicate significant influence of the interaction of stitch densities and wash cycles on seam strength, efficiency and elongation both in the warp and weft directions. It can be deduced from this finding that from the current study variation of stitch density and wash cycle influenced the seam performance properties (strength, efficiency and elongation). None of the reviewed works examined the interaction of stitch density and wash cycle on seam performance properties. Therefore no comparison could be made with the reviewed literature.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Study

The aim of the study was to select a suitable fabric from the fabrics currently used for Ghanaian public basic school uniforms and evaluate seam performance characteristics of the selected fabric. The study was conducted in two phases (phase one and two). An experimental design was employed for both phases. In the phase one, the performance characteristics of three brands of fabrics currently used for public basic school uniforms in Ghana were evaluated. The performance characteristics investigated included fabric breaking strength, colourfastness, shrinkage, weight and absorbency. Based on the results, one fabric was selected for the phase two.

The phase two of the study involved seam performance properties evaluation on the fabric selected. The seam evaluation involved the use of two brands of sewing threads, three ranges of stitch densities and three wash cycles. The performance characteristics assessed were seam strength, efficiency and elongation. The total number of specimens used for phase one was 366 and for phase two, 240. The instruments used for the collection of the data in both phases of the study included the Standard Launder-Ometer (Gyrowash 315), butterfly hand sewing machine, tensile testing machine (Mark-10 Force Gauge Model M5-500), magnifying glass, weighing balance (Adams equipment), colour assessment chamber, a pair of scissors and sample cutter (Appendix B). The study was carried out at the textile laboratories of the Ghana Standards Authority and Materials Science Department of the School of Engineering, University of Ghana, Legon. The data obtained were analysed by the use

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of means, standard deviations and Inferential Statistics(Analysis of Variance and Independent samples *t*-test at 0.05 alpha levels). The results were presented in Tables and graphs.

5.2. Summary of the Findings

Phase One Findings

1. All the investigated fabrics contained varied proportions of polyester and cellulose (either viscose or cotton) fibres with polyester being higher in all the fabrics.
2. The fabrics met the standard specifications for all the parameters indicated in the GS 970:2009, except the brand A which failed on the basis of the strength requirements. The fabric brand C failed in terms of absorbency which was not indicated in the GS 970:2009. In all the parameters evaluated for fabric performance characteristics, the fabric brand B performed very well.
3. It was observed that the GS 970:2009 did not cover other important parameters that are required to determine the suitability of fabrics for uniforms especially in the tropics such as absorbency. Fabrics yarn count, linear density and elongation were other parameters that were not catered for in the GS 970:2009.
4. Statistical analysis showed significant differences among the uniform fabrics used for the study in terms of weight, yarn count, shrinkage, strength and elongation characteristics.

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5. Number of times of washing was noted to influence the strength and elongations of the uniform fabrics studied, but not their weight. For shrinkage and colourfastness, washing cycle did not exhibit much effect on the fabrics.

Phase Two Findings

6. The uniform fabric used for seam performance evaluation was stronger than all the seams stitched with the two thread brands in the three SPIs selected for the study after three wash cycles. Seams stitched with thread brand B′ in 14 SPI had higher percentage elongations than the fabric in all the wash cycles.
7. It was observed that differences for seam strength, efficiency and elongation were significant for the two sewing thread brands used for the study in both warp and weft directions. Sewing thread brand B′ produced greater seam strength, efficiency and elongation than brand A′ in both directions.
8. Differences for seam strength, efficiency and elongation were found to be significant for the three stitch densities in both warp and weft seams. As stitch density increased, seam strength, efficiency and elongation increased with 14 SPI performing above 10 and 12 SPIs.
9. It was observed that differences existed between the wash cycles used for the study in terms of seam strength, efficiency and elongation of all the seams (see figures 4.9, 4.10, 4.11).
10. Sewing thread brands, stitch densities and wash cycles combined were found not to have significant influence on seam strength, elongation and efficiency in both directions. However, the combined influence of stitch densities and wash cycles on seam strength, elongation and efficiency were found to be significant in both warp and weft directions.

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5.3 Conclusions

The study revealed that fabric brand B which was a blend of cotton and polyester was the most suitable for Ghanaian public basic school uniforms in terms of all the fabric characteristics studied before and after washing. Sewing thread brand B′ gave greater seam strength, efficiency and elongation before and after washing, indicating a suitable thread for seams in the selected suitable fabric for Ghanaian public basic school uniforms. The 14 stitches per inch had the highest seam strength, efficiency and elongation before and after washing, indicating a suitable stitch density for seams in the selected suitable fabric for Ghanaian public basic school uniforms. The seams in 10 and 12 SPIs of both sewing thread brands used for the study did not perform very well. It is however, not surprising that seams in the mass produced uniform garments currently used by pupils fail at early stages of use as they are in low SPIs such as 6 and 7.

5.3.1 Linking Findings with the Conceptual Framework

The conceptual framework that guided the study provided an understanding of the interaction of the variables assessed, in contributing to the overall quality of school uniforms. The findings of the study have confirmed the contribution of each variable such as fabric fibre type, strength and absorbency and stitches per inch, seam strength and efficiency indicated in the conceptual framework in achieving good quality school uniforms. A suitable fabric, sewing thread brand and stitch density that would help achieve good quality school uniforms for public basic school pupils in Ghana have been documented.

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5.4 Limitations of the Study

The study did not examine all fabrics and sewing thread brands available on the market and used for school uniforms. Studying a wider range of fabric and sewing thread brands on the market could help recommend a number of fabric brands and sewing threads that could be used to achieve good quality school uniforms. In addition, only one type of fabric from the recommended brand was used for seam analysis and so the results cannot be generalized outside the type of fabric used.

5.5 Recommendations

Based on the findings and the conclusions of the current study, the following have been suggested.

1. Since the GS 970:2009 did not indicate certain parameters that would help to better establish the suitability of fabrics for school uniforms, it is recommended that; the Ghana Standards Authority reviews the GS 970:2009 to include yarn count, yarn linear density, elongation and absorbency properties of fabrics that would help to better establish the suitability of fabrics for school uniforms in the Ghanaian climate.
2. Since sewing thread brands and stitch densities were found to influence seam performance properties. It is suggested that; Outreach programmes, seminars, workshops and conferences are organised by the Ghana Standards Authority and academia, for instance, the Family and Consumer Sciences Department of the University of Ghana, Legon to educate garment manufacturers on the need to select appropriate sewing threads and stitch densities in the construction of durable school uniforms.

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3. Since fabric brand B was noted as suitable for public basic school uniforms and sewing thread brand B′ with 14 SPI were found to produce higher seam strength, efficiency and elongation in the selected suitable fabric. It is suggested that the Association of Ghana Apparel Manufacturers (AGAM) encourage the members to make use of such fabrics, sewing threads and stitch densities for good quality public basic school uniforms.

Suggestions for further research

1. Further research on seam analysis needs to be conducted on the other colour type of the fabric brand that met the Ghana Standards Authority's requirements. This would offer garment manufacturers a solid foundation to make decisions regarding the use of sewing threads and stitch densities in school uniform production.
2. Further research is needed to identify additional fabrics and sewing thread brands that can aid to achieve good quality school uniforms. Researches should also be conducted on the range of fabrics on the Ghanaian market to determine their quality and suitability for the purposes for which they are used such as for lining and children's garments. Findings from such researches would aid in educating fabric manufacturers on the need to produce fabrics that meet requirements for specific end-uses.
3. It is suggested that various tests are carried out on variety of sewing thread brands with different stitch lengths on a range of fabrics in the Ghanaian market. Testing other variables and publishing works on this relationship will offer future educators, scholars, students and garment manufacturers a solid

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foundation to make informed decisions regarding the use of sewing threads and stitch densities in clothing construction.

4. Further research could be conducted on the same fabrics used for the current research where additional parameters such as colourfastness to perspiration and abrasion resistance would be evaluated, since the scope of this research could not cover these two other performance characteristics.

5.6 Implications of the Findings

From the knowledge gained by investigating the suitability of fabrics currently used for Ghanaian public basic school uniforms and seam performance of a suitable fabric, individuals would understand better the problem areas of poor quality experienced in school uniforms and garments in general. The information gained can help in many ways. The new knowledge obtained could have policy and educational implications.

A. Policy Implication

The Ghana Standards Authority as a government agency has the mandate of ensuring that products are of good quality.

i. The Authority as a regulator should ensure that policies regarding the testing of fabrics on the markets are enforced. This would enable consumers be assured of the quality of fabrics in the market and help achieve desired results from fabrics purchased.

i. If possible, mass production of school uniforms should be assigned to particular garment industries to produce school uniforms in suitable fabrics with appropriate sewing threads and stitch densities.

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B. Educational Implication

Children spend approximately 10 hours a day in their school uniforms; consequently, school uniforms must be comfortable and of good quality. The Ghana Standards Authority and Academia, for instance, the Department of Family and Consumer Sciences should therefore educate garment manufacturers to select the right type of fabrics, sewing threads and stitch densities so that good quality school uniforms suitable for the Ghanaian environment are produced.

When school uniform manufacturers are able to build quality into the uniforms by selecting the right fabrics, sewing threads and stitch densities, prices of the uniforms would certainly go up. However, it would be better than buying the cheap ones that parents would have to replace within three to six months of use as well as pay more to maintain. It will therefore be prudent for stakeholders in the garment industry to educate parents about the value of good quality uniforms.

5.7 Research Contribution to Knowledge

This research is unique as it assessed two variables of intrinsic quality cues (fabric and seam) used to determine garment quality in combination with a condition of use (washing). The study has documented a suitable fabric for school uniforms in Ghana and also, a suitable sewing thread brand and a stitch density that would help achieve good quality school uniforms.

The study has created the awareness that the GS 970:2009 does not cover parameters such as fabric absorbency, yarn linear density and elongation needed to determine the overall suitability of fabrics for uniforms in Ghana.

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The current study confirms the scientific basis for the conventional practice which is the use of different stitch densities and thread types in sewing different fabric types. Additionally, the study has added to knowledge that the interaction of stitch densities and wash cycles has influence on seam strength, elongation and efficiency.

Previous literature that fabric type, thread type and stitch density have influence on the performance of seams in garments have been confirmed and information has been provided that the different thread brands in the Ghanaian market are likely to produce different seam performances. These might serve as a basic point of reference for further research.

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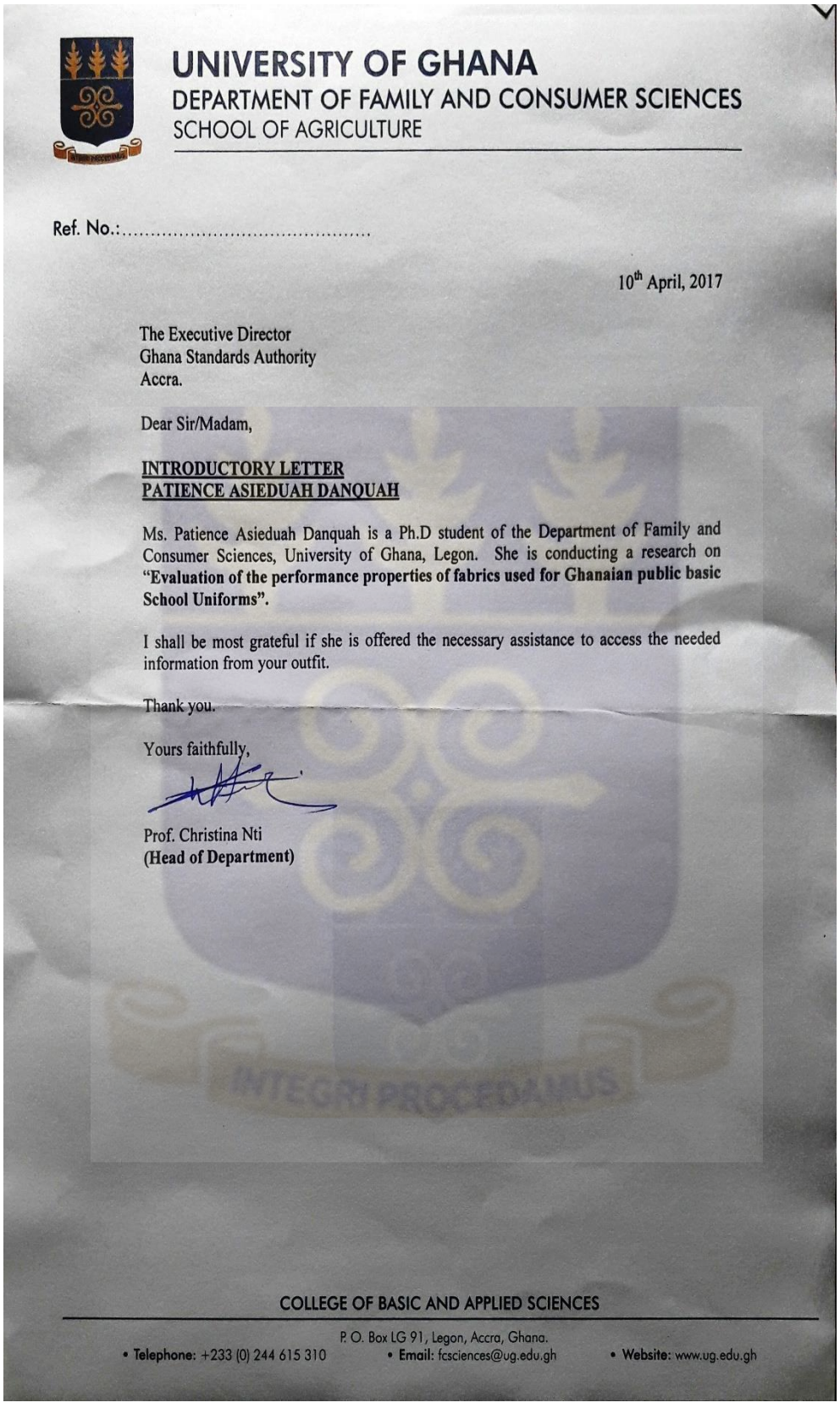
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APPENDICES

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APPENDIX A:PICTURE OF THE INTRODUCTORY LETTER TAKEN TO GSA



UNIVERSITY OF GHANA
DEPARTMENT OF FAMILY AND CONSUMER SCIENCES
SCHOOL OF AGRICULTURE

Ref. No.:.....

10th April, 2017

The Executive Director
Ghana Standards Authority
Accra.

Dear Sir/Madam,

INTRODUCTORY LETTER
PATIENCE ASIEDUAH DANQUAH

Ms. Patience Asieduah Danquah is a Ph.D student of the Department of Family and Consumer Sciences, University of Ghana, Legon. She is conducting a research on **"Evaluation of the performance properties of fabrics used for Ghanaian public basic School Uniforms".**

I shall be most grateful if she is offered the necessary assistance to access the needed information from your outfit.

Thank you.

Yours faithfully,

Prof. Christina Nti
(Head of Department)

INTEGRI PROCEDAMUS

COLLEGE OF BASIC AND APPLIED SCIENCES

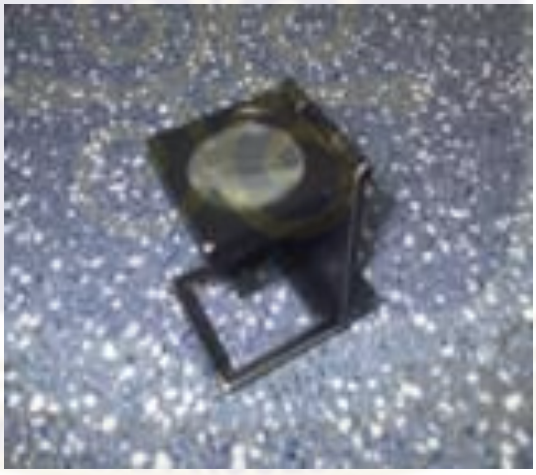
P. O. Box LG 91, Legon, Accra, Ghana.
• Telephone: +233 (0) 244 615 310 • Email: fcsciences@ug.edu.gh • Website: www.ug.edu.gh

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APPENDIX B: PICTURES OF SOME OF THE INSTRUMENTS USED FOR THE INVESTIGATIONS

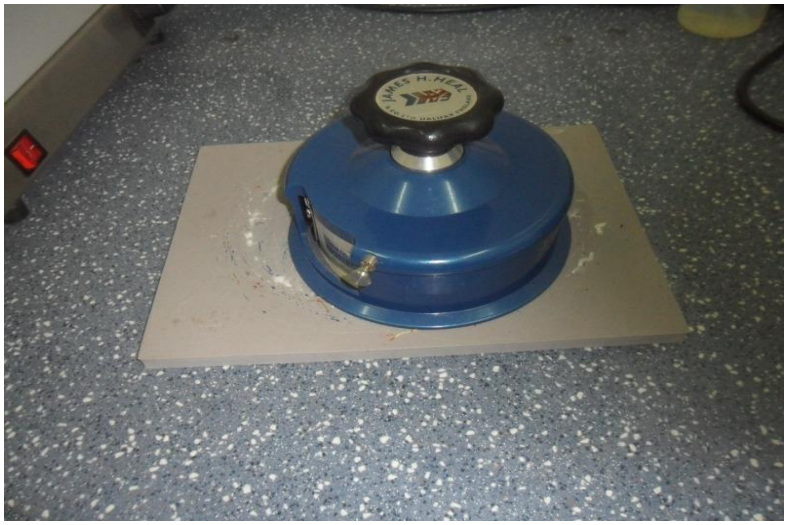


Weighing balance (Adams equipment, B215846278)



Magnifying glass

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Sample cutter (James H. Heal, 230/002595)

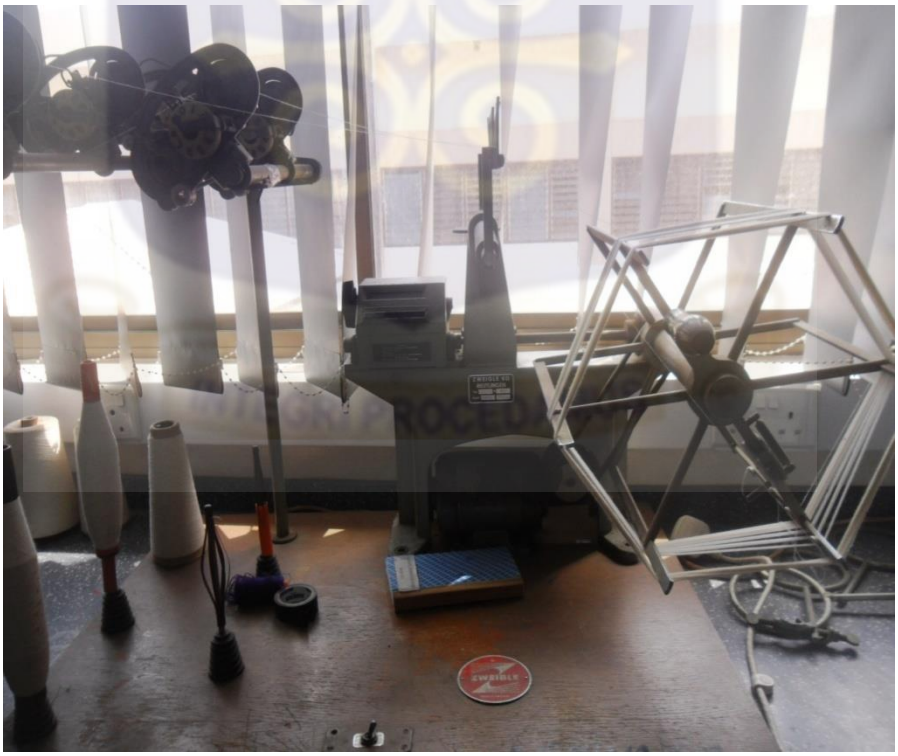


Washing machine (Standard Launder-Ometer, Gyrowash 315)

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Tensile testing machine (Mark-10 Force Gauge Model M5-500)



The Wrap Reel

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Colour Assessment Chamber

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APPENDIX C: DISTRIBUTION OF TOTAL NUMBER OF SPECIMENS USED FOR PHASE ONE OF THE STUDY

Tables 1 and 2 present the breakdown for the specimens used for the phase one of the study. Based on the standard test methods used, 61 specimens (40 in Table 1, 21 in Table 2) were randomly cut from each fabric type. A total of 366 specimens were therefore used for the various experiments in phase one of the study.

Table 1:Distribution of total number of specimens used for evaluating the fabrics strength and elongation

	No. of specimens unwashed		No. of specimens washed once		No. of specimens washed twice		No. of specimens washed three times		
Fabric Direction	Warp	Weft	Warp	Weft	Warp	Weft	Warp	weft	**Total**
Fabric Types									
A1	5	5	5	5	5	5	5	5	40
A2	5	5	5	5	5	5	5	5	40
B1	5	5	5	5	5	5	5	5	40
B2	5	5	5	5	5	5	5	5	40
C1	5	5	5	5	5	5	5	5	40
C2	5	5	5	5	5	5	5	5	40
Total									**240**

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Table 2: Distribution of total number of specimens used for testing fabric weight, colourfastness, shrinkage, fabric count, yarn linear density and weave type

Type of Test	A 1	A 2	B1	B2	C1	C2	Total no. of specimens
Fabric weight	5	5	5	5	5	5	**30**
Colourfastness	2	2	2	2	2	2	**12**
Dimensional stability (shrinkage)	2	2	2	2	2	2	**12**
Woven Fabric Count	3	3	3	3	3	3	**18**
Weave type	1	1	1	1	1	1	**6**
Yarn linear density	7	7	7	7	7	7	**42**
Absorbency	1	1	1	1	1	1	**6**
Total	21	21	21	21	21	21	**126**
Grand Total of specimens from Tables 1 and 2							**366**

A1, A2, B1, B2, C1, C2= Fabric types

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APPENDIX D: LABELS FOR SPECIMENS USED FOR PHASE ONE OF THE STUDY

Labelling of the specimens was done based on the brand of fabric, direction of the specimen (warp and weft) and the number of washes the specimen had. All fabric brand A specimens were labelled 'A', all brand B specimens were labelled 'B' and all C specimens were labelled 'C'. All warp specimens were labelled 'P' and weft specimens labelled 'T'. Specimens washed once were labelled 1, twice, 2 and three times 3. For instance, A1P, B1P and C1P represented the first colour of the three brands of fabrics used for the study in warp direction that were not washed. The other labels are presented in Tables 3 and 4.

Table 3: Specimen labels for fabric yarn count, yarn linear density, fibre type, weave type and absorbency

Yarn Count		Yarn Linear Density					NO. of wash cycles
Warp specimens	Weft specimens	Warp specimens	Weft specimens	Fibre Type	Weave Type	Absorbency	
A1P	A1T	A1P	A1T	A1	A1	A1	0
B1P	B1T	B1P	B1T	A2	A2	A2	
CIP	CIT	CIP	CIT	B1	B1	B1	
A2P	A2T	A2P	A2T	B2	B2	B2	
B2P	B2T	B2P	B2T	C1	C1	C1	
C2P	C2T	C2P	C2T	C2	C2	C2	

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Table 4: Specimen labels for fabric strength, elongation, shrinkage, colourfastness and weight

Fabric Strength/ Elongation		Shrinkage		Colourfastness	Weight	Number of wash cycles
Warp	Weft	Warp	Weft			
A1P	A1T	A1P	A1T	A1CC	A1W	0
B1P	B1T	B1P	B1T	B1CC	A2W	
CIP	CIT	CIP	CIT	C1CC	B1W	
A2P	A2T	A2P	A2T	A2CC	B2W	
B2P	B2T	B2P	B2T	B2CC	C1W	
C2P	C2T	C2P	C2T	C2CC	C2 W	
A1P1	A1T1	A1P1	A1T1	A1CC1	A1W1	1
B1P1	B1T1	B1P1	B1T1	B1CC1	B1W1	
C1P1	C1T1	C1P1	C1T1	C1CC1	C1W1	
A2P1	A2T1	A2P1	A2T1	A2CC1	A2W1	
B2P1	B2T1	B2P1	B2T1	B2CC1	B2W1	
C2P1	C2T1	C2P1	C2T1	C2CC1	C2W1	

Note: The specimens washed two and three times were also labelled.

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APPENDIX E:DISTRIBUTION OF TOTAL NUMBER OF SPECIMENS USED FOR PHASE TWO OF THE STUDY

Table 5 shows the distribution of total number of specimens used for phase two of the study. From Table 5 it can be noted that to test for seam strength and elongation, eighty specimens were used for each SPI (see area coloured green in Table 5), where each thread used 5 specimens in the warp direction and 5 in the weft direction for each wash cycle. Twenty out of the 80 specimens served as controls (see area coloured blue in Table 5), and the remaining 60 specimens (see area coloured yellow in Table 5) for each SPI were used for the three wash cycles, with each cycle making use of 20 specimens. In all, each brand of sewing thread was used to sew 80 specimens (40 in the warp direction and 40 in the weft direction) making a total of 240 specimens in both warp and weft directions of the fabric.

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Table 5: Distribution of total number of specimens used for seam evaluation

	No. of specimens that were unwashed		No. of specimens washed once		No. of specimens washed twice		No. of specimens washed three times		
Fabric Direction	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	**Total No. of specimens**
Thread A′ 10 SPI	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**40**
Thread B′ 10 SPI	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**40**
Thread A′ 12 SPI	5	5	5	5	5	5	5	5	40
Thread B′ 12 SPI	5	5	5	5	5	5	5	5	40
Thread A′ 14 SPI	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**40**
Thread B′ 14 SPI	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**40**
TOTAL	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**240**

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APPENDIX F: LABELS FOR SPECIMENS USED FOR PHASE TWO OF THE STUDY

Table 6:Specimen labels for seam performance evaluation

Specimen label (seam strength /elongation)		Number of wash cycles
Warp	Weft	
AP10 BP10	AT10 BT10	0
AP12 BP12	AT12 BT12	0
AP14 BP14	AT14 BT14	0
AP101 BP101	AT101 BT101	1
AP121 BP121	AT121 BT121	1
AP141 BP141	AT141 BT141	1
AP102 BP102	AT102 BT102	2
AP122 BP122	AT122 BT122	2
AP142 BP142	AT142 BT142	2

Note: The specimens washed three times were also labelled.

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Labelling of the specimens was done based on the direction of the specimen (warp, weft), the sewing thread brand (A′ and B′), the SPI and the number of washes the specimen had. All thread brand A′ specimens were labelled ‘A’ and all brand B′ thread specimens were labelled ‘B’. Specimens stitched in 10 SPI were labelled 10 and same done for 12 and 14 SPI. All warp specimens were labelled ‘P’ and weft specimens labelled ‘T’. Specimens washed once were labelled 1, two times were labelled 2 and three times were labelled 3. For instance, AP101 and BP101 represented warp specimens that were washed once and AP102 and BP102 represented warp specimens that were washed two times (Table 6). This was done for the other stitch densities, which were 12 and 14 and the weft specimens as well (see Table 6).

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APPENDIX G: POST HOC TUCKEY HSD RESULTS

Table 7: Post Hoc results for multiple comparisons for fabric brands × weights

Fabric Brand	MD	*P-value*
A1×B1	33.899	0.001*
A1×B2	33.510	0.001*
A1×C1	50.680	0.001*
A1×C2	64.731	0.001*
A2×A1	2.181	0.001*
A2×B1	36.081	0.001*
A2×B2	35.692	0.001*
A2×C1	52.861	0.001*
A2×C2	66.912	0.001*
B1×C1	16.781	0.001*
B1×C2	30.831	0.001*
B2×B1	0.389	0.001*
B2×C1	17.169	0.001*
B2×C2	31.220	0.001*
C1×C2	14.051	0.001*

**Significant p<0.05, MD= Mean Difference*

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Table 8: Post Hoc results for multiple comparisons for fabric brands × their strengths

Fabric Brand/Fabric Direction	MD	*P-value*
Warp		
A2×A1	81.625	0.001*
A2×B1	77.325	0.001*
A2×C1	75.175	0.001*
A2×C2	94.125	0.001*
B2×A1	48.250	0.023*
B2×C2	60.750	0.002*
Weft		
A1×C2	46.850	0.003*
A2×B1	40.950	0.014*
A2×C1	37.200	0.034*
A2×C2	78.550	0.001*
B1×C2	37.600	0.031*
B2×C2	67.075	0.001*
C1×C2	41.350	0.012*

**Significant p<0.05, MD= Mean Difference*

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Table 9: Post Hoc results for multiple comparisons for fabric brands × their breaking elongations

Fabric Brand/Fabric Direction	MD	*P-value*
Warp		
B1×A1	5.311	0.049*
B1×C2	5.729	0.026*
C1×A1	5.346	0.046*
C1×C2	5.765	0.024*
Weft		
A2×A1	5.000	0.007*
A2×C1	7.294	0.001*
A2× C2	5.626	0.002*
B2×A1	7.083	0.001*
B2×B1	5.209	0.005*
B2×C1	9.377	0.001*
B2×C2	7.709	0.001*

**Significant p<0.05, MD= Mean Difference*

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Table 10: Post Hoc results for multiple comparisons for fabric brands × shrinkage

Fabric Brand/Fabric Direction	MD	*P-value*
Warp		
A2×A1	1.000	0.009*
A2×B2	1.467	0.001*
A2×C1	1.133	0.002*
A2×C2	1.267	0.001*
B1×B2	1.133	0.002*
B1×C2	0.933	0.018*
Weft		
A1×B1	1.133	0.001*
A1×B2	1.133	0.001*
A1× C1	0.933	0.024*
A1×C2	1.333	0.001*
A2×B1	1.067	0.002*
A2×B2	1.067	0.002*
A2×C1	0.867	0.024*
A2×C2	1.333	0.001*

**Significant p<0.05, MD= Mean Difference*

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Table 11: Post Hoc results for multiple comparisons for fabric brands ×yarn counts

Fabric Direction /Fabric Brand	MD	*P-value*
Warp		
B1×A1	5.400	0.018*
B2×A1	6.200	0.005*
C1×A1	25.600	0.001*
C1×A2	24.000	0.001*
C1×B1	20.200	0.001*
C1×B2	19.400	0.001*
C2×A1	23.600	0.001*
C2×A2	22.000	0.001*
C2×B1	18.200	0.001*
C2×B2	17.400	0.001*
Weft		
A1×B1	5.200	0.023*
A2×B1	7.000	0.001*
A2×B2	5.400	0.017*
C1×A1	18.800	0.001*
C1×A2	17.000	0.001*
C1×B1	24.000	0.001*
C1×B2	22.400	0.001*
C2×A1	16.800	0.001*
C2×A2	15.000	0.001*
C2×B1	22.000	0.001*
C2×B2	20.400	0.001*

**Significant p<0.05, MD= Mean Difference*

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Table 12: Post Hoc results for multiple comparisons for fabric strengths × wash cycles, elongation× wash cycles

Fabric Direction /wash cycles	MD	*P-value*
Strength **Weft** Unwashed × 3rd Wash	34.417	0.015*
Elongation **Warp**		
3rd Wash × Unwashed	4.837	0.010*
3rd Wash × 2nd wash	4.444	0.021*

**Significant p<0.05, MD= Mean Difference*

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Table 13: Post Hoc results for multiple comparisons for seam strength, efficiency and elongation × stitch densities

Fabric direction/wash cycle	MD	*p-value*
Strength		
Warp		
14×10	53.888	0.001*
14×12	41.963	0.001*
Weft		
12×10	31.513	0.003*
14×10	88.988	0.001*
14×12	57.475	0.001*
Efficiency		
Warp		
14×10	14.904	0.001*
14×12	11.779	0.001*
Weft		
12×10	7.500	0.005*
14×10	20.910	0.001*
14×12	13.410	0.001*
Elongation		
Warp		
14×10	1.996	0.001*
14×12	9.537	0.001*
Weft		
14×10	9.718	0.001*
14×12	8.947	0.001*

**Significant p<0.05, M=Mean difference*

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Table 14: Post Hoc results for multiple comparisons for seam strength, efficiency and elongation × wash cycles

Fabric direction/wash cycle	MD	*p-value*
Strength **Warp**		
Unwashed×1st Wash	34.633	0.004*
Unwashed×2nd Wash	28.367	0.028*
Unwashed×3rd Wash	27.767	0.033*
Efficiency **Weft**		
Unwashed×1st Wash	9.128	0.043*
Elongation **Warp**		
2nd Wash × Unwashed	6.322	0.004*

**Significant p<0.05, M=Mean difference*

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APPENDIX H: ADDITIONAL RESULTS FROM 3-WAY ANOVA

Table 15:Summarised results from the 3-way ANOVA on the influence of stitch density × wash cycle on seam strength, elongation and efficiency

Source	df	MD	*F*	*p*-value
Strength				
Warp				
Stitch density and Wash cycle	6	1704.228	2.409	0.033*
Weft				
Stitch density and Wash cycle	6	1579.653	5.196	0.001*
Elongation				
Warp				
Stitch density and Wash cycle	6	96.597	6.432	0.001*
Weft				
Stitch density and Wash cycle	6	11.635	2.313	0.040*
Efficiency				
Warp				
Stitch density and Wash cycle	6	140.020	2.393	0.034*
Weft				
Stitch density and Wash cycle	6	115.896	6.785	0.001*

**Significant p<0.05, M=Mean Square*

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APPENDIX I: INFERENTIAL STATISTICS RESULTS

Appendix I. a: Test of homogeneity of variances, Robust tests of equality of means and ANOVA test for determining differences among the investigated fabrics strengths, elongations, weights, shrinkage and yarn counts

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Fabric strength warp	2.080	5	114	.073
Fabric elongation warp	4.158	5	114	.002
Fabric strength weft	5.673	5	114	.000
Fabric elongation weft	.927	5	114	.466
Yarn count warp	4.210	5	24	.007
Yarn count weft	1.344	5	24	.280
Shrinkage warp	2.141	5	84	.068
Shrinkage weft	1.777	5	84	.126
Weight	3.622	5	114	.004

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
Fabric strength warp	Welch	19.364	5	52.485	.000
Fabric elongation warp	Welch	5.617	5	52.360	.000
Fabric strength weft	Welch	17.747	5	52.130	.000
Fabric elongation weft	Welch	12.449	5	52.862	.000
Yarn count warp	Welch	141.037	5	10.854	.000
Yarn count weft	Welch	92.371	5	10.638	.000
Shrinkage warp	Welch	14.564	5	38.668	.000
Shrinkage weft	Welch	12.225	5	38.891	.000
Weight	Welch	4479.141	5	51.562	.000

a. Asymptotically F distributed.

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ANOVA

Variables		Sum of Squares	df	Mean Square	F	Sig.
Fabric strength warp	Between Groups	129420.860	5	25884.172	11.258	.000
	Within Groups	262098.888	114	2299.113		
	Total	391519.748	119			
Fabric elongation warp	Between Groups	696.851	5	139.370	4.183	.002
	Within Groups	3798.134	114	33.317		
	Total	4494.985	119			
Fabric strength weft	Between Groups	74181.494	5	14836.299	9.928	.000
	Within Groups	170352.488	114	1494.320		
	Total	244533.981	119			
Fabric elongation weft	Between Groups	1280.568	5	256.114	12.865	.000
	Within Groups	2269.509	114	19.908		
	Total	3550.077	119			
Yarn count warp	Between Groups	3167.600	5	633.520	108.915	.000
	Within Groups	139.600	24	5.817		
	Total	3307.200	29			
Yarn count weft	Between Groups	2712.967	5	542.593	95.471	.000
	Within Groups	136.400	24	5.683		
	Total	2849.367	29			
Shrinkage warp	Between Groups	24.667	5	4.933	8.136	.000
	Within Groups	50.933	84	.606		
	Total	75.600	89			
Shrinkage weft	Between Groups	26.622	5	5.324	9.584	.000
	Within Groups	46.667	84	.556		
	Total	73.289	89			
Weight	Between Groups	71938.967	5	14387.793	5803.365	.000
	Within Groups	282.631	114	2.479		
	Total	72221.597	119			

Note: For a variable that violates the assumption of Homogeneity of Variances, the Significant value in the Welch test was reported.

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Appendix I. b: Test of homogeneity of variances, Robust tests of equality of means and ANOVA test for determining differences between wash cycles and the investigated fabrics strengths, elongations, weights and shrinkage

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Fabric strength warp	2.808	3	116	.043
Fabric strength weft	1.375	3	116	.254
Fabric elongation warp	9.730	3	116	.000
Fabric elongation weft	3.239	3	116	.025
Shrinkage warp	.105	2	87	.900
Shrinkage weft	3.571	2	87	.032
Weight	.112	3	116	.953

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
Fabric strength warp	Welch	2.592	3	63.983	.041
Fabric strength weft	Welch	4.078	3	64.146	.010
Fabric elongation warp	Welch	5.020	3	62.225	.004
Fabric elongation weft	Welch	1.858	3	61.801	.146
Shrinkage warp	Welch	.849	2	57.945	.433
Shrinkage weft	Welch	.992	2	57.214	.377
Weight	Welch	.010	3	64.420	.999

a. Asymptotically F distributed.

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ANOVA

Variables		Sum of Squares	df	Mean Square	F	Sig.
Fabric strength warp	Between Groups	26248.406	3	8749.469	2.779	.044
	Within Groups	365271.342	116	3148.891		
	Total	391519.748	119			
Fabric strength weft	Between Groups	23829.956	3	7943.319	4.175	.008
	Within Groups	220704.025	116	1902.621		
	Total	244533.981	119			
Fabric elongation warp	Between Groups	498.386	3	166.129	4.822	.003
	Within Groups	3996.599	116	34.453		
	Total	4494.985	119			
Fabric elongation weft	Between Groups	172.052	3	57.351	1.969	.122
	Within Groups	3378.025	116	29.121		
	Total	3550.077	119			
Shrinkage warp	Between Groups	1.400	2	.700	.821	.443
	Within Groups	74.200	87	.853		
	Total	75.600	89			
Shrinkage weft	Between Groups	1.489	2	.744	.902	.410
	Within Groups	71.800	87	.825		
	Total	73.289	89			
Weight	Between Groups	17.686	3	5.895	.009	.999
	Within Groups	72203.911	116	622.448		
	Total	72221.597	119			

Note: For a variable that violates the assumption of Homogeneity of Variances, the Significant value in the Welch test was reported.

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Appendix I. c: Group statistics and Independent Samples *t*-test for determining significant differences between thread brands and seam strength, efficiency and elongation

Group Statistics

	Thread brands	N	Mean	Std. Deviation	Std. Error Mean
Seam strength warp	A′	60	178.8500	33.28273	4.29678
	B′	60	206.4000	43.01180	5.55280
Seam strength weft	A′	60	192.7333	32.76709	4.23021
	B′	60	261.9250	52.23925	6.74406
Seam elongation warp	A′	60	36.4277	7.31371	.94420
	B′	60	39.6670	6.98558	.90183
Seam elongation weft	A′	60	20.2707	3.14012	.40539
	B′	60	25.6808	7.09758	.91629
Seam efficiency warp	A′	60	50.6613	9.45292	1.22037
	B′	60	58.4580	11.66412	1.50583
Seam efficiency weft	A′	60	44.9400	8.13874	1.05071
	B′	60	61.2000	13.02254	1.68120

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_t_-test for Equality of Means

						95% Confidence Interval of the Difference	
Variables	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Seam strength warp	-3.924	118	.000	-27.55000	7.02111	-41.45370	-13.64630
	-3.924	111.009	.000	-27.55000	7.02111	-41.46278	-13.63722
Seam strength weft	-8.691	118	.000	-69.19167	7.96097	-84.95655	-53.42678
	-8.691	99.203	.000	-69.19167	7.96097	-84.98756	-53.39578
Seam elongation warp	-2.481	118	.015	-3.23933	1.30568	-5.82494	-.65372
	-2.481	117.752	.015	-3.23933	1.30568	-5.82500	-.65367
Seam elongation weft	-5.400	118	.000	-5.41017	1.00196	-7.39433	-3.42600
	-5.400	81.245	.000	-5.41017	1.00196	-7.40367	-3.41666
Seam efficiency warp	-4.023	118	.000	-7.79667	1.93825	-11.63493	-3.95840
	-4.023	113.145	.000	-7.79667	1.93825	-11.63664	-3.95669
Seam efficiency weft	-8.202	118	.000	-16.26000	1.98253	-20.18595	-12.33405
	-8.202	98.989	.000	-16.26000	1.98253	-20.19378	-12.32622

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Appendix I. d: Test of homogeneity of variances, Robust tests of equality of means and ANOVA test for determining differences between stitch densities and seam strength, efficiency and elongation

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Seam strength warp	3.714	2	117	.027
Seam strength weft	19.087	2	117	.000
Seam elongation warp	1.547	2	117	.217
Seam elongation weft	63.353	2	117	.000
Seam efficiency warp	3.121	2	117	.048
Seam efficiency weft	13.012	2	117	.000

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
Seam strength warp	Welch	21.184	2	73.982	.000
Seam strength weft	Welch	38.924	2	75.557	.000
Seam elongation warp	Welch	55.691	2	77.547	.000
Seam elongation weft	Welch	39.008	2	71.680	.000
Seam efficiency warp	Welch	21.859	2	73.073	.000
Seam efficiency weft	Welch	35.497	2	74.995	.000

a. Asymptotically F distributed.

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ANOVA

Variables		Sum of Squares	df	Mean Square	F	Sig.
Seam strength warp	Between Groups	64092.262	2	32046.131	28.152	.000
	Within Groups	133185.363	117	1138.336		
	Total	197277.625	119			
Seam strength weft	Between Groups	162869.179	2	81434.590	46.452	.000
	Within Groups	205110.069	117	1753.078		
	Total	367979.248	119			
Seam elongation Warp	Between Groups	3212.068	2	1606.034	59.885	.000
	Within Groups	3137.759	117	26.818		
	Total	6349.826	119			
Seam elongation weft	Between Groups	2334.507	2	1167.253	65.110	.000
	Within Groups	2097.514	117	17.927		
	Total	4432.021	119			
Seam efficiency warp	Between Groups	4941.862	2	2470.931	28.396	.000
	Within Groups	10180.923	117	87.016		
	Total	15122.786	119			
Seam efficiency weft	Between Groups	8977.416	2	4488.708	40.813	.000
	Within Groups	12867.921	117	109.982		
	Total	21845.337	119			

Note: For a variable that violates the assumption of Homogeneity of Variances, the Significant value in the Welch test was reported.

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Appendix I. e: Test of homogeneity of variances, Robust tests of equality of means and ANOVA test for determining differences between wash cycles and seam strength, efficiency and elongation

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Seam strength warp	1.133	3	116	.339
Seam strength weft	.853	3	116	.468
Seam elongation warp	4.164	3	116	.008
Seam elongation weft	.761	3	116	.518
Seam efficiency warp	.750	3	116	.525
Seam efficiency weft	1.609	3	116	.191

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
Seam strength warp	Welch	3.932	3	64.160	.012
Seam strength weft	Welch	.323	3	64.113	.809
Seam elongation warp	Welch	4.971	3	63.639	.004
Seam elongation weft	Welch	.030	3	64.220	.993
Seam efficiency warp	Welch	2.835	3	64.315	.045
Seam efficiency weft	Welch	2.596	3	63.733	.060

a. Asymptotically F distributed.

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ANOVA

Variables		Sum of Squares	df	Mean Square	F	Sig.
Seam strength warp	Between Groups	21464.292	3	7154.764	4.721	.004
	Within Groups	175813.333	116	1515.632		
	Total	197277.625	119			
Seam strength weft	Between Groups	3428.073	3	1142.691	.364	.779
	Within Groups	364551.175	116	3142.683		
	Total	367979.248	119			
Seam Elongation warp	Between Groups	636.945	3	212.315	4.311	.006
	Within Groups	5712.881	116	49.249		
	Total	6349.826	119			
Seam elongation weft	Between Groups	3.564	3	1.188	.031	.993
	Within Groups	4428.457	116	38.176		
	Total	4432.021	119			
Seam Efficiency warp	Between Groups	1061.684	3	353.895	2.920	.037
	Within Groups	14061.102	116	121.216		
	Total	15122.786	119			
Seam Efficiency weft	Between Groups	1427.193	3	475.731	2.703	.049
	Within Groups	20418.144	116	176.018		
	Total	21845.337	119			

Note: For a variable that violates the assumption of Homogeneity of Variances, the Significant value in the Welch test was reported.

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Appendix I. f: Test of between-subjects effects for determining influence of thread brands, stitch densities and wash cycles on seam strength, elongation and efficiency

Tests of Between-Subjects Effects

Dependent Variable: Seam strength warp

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	129357.725[a]	23	5624.249	7.949	.000
Intercept	4452526.875	1	4452526.875	6293.333	.000
Thread brand	22770.075	1	22770.075	32.184	.000
Stitch density	64092.263	2	32046.131	45.295	.000
Wash cycle	21464.292	3	7154.764	10.113	.000
Thread brand * stitch density	2101.663	2	1050.831	1.485	.232
Thread brand * wash cycle	5196.825	3	1732.275	2.448	.068
Stitch density * wash cycle	10225.371	6	1704.228	2.409	.033
Thread brand * stitch density * wash cycle	3507.237	6	584.540	.826	.552
Error	67919.900	96	707.499		
Total	4649804.500	120			
Corrected Total	197277.625	119			

a. R Squared = .656 (Adjusted R Squared = .573)

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Tests of Between-Subjects Effects

Dependent Variable: Seam strength weft

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	338796.448[a]	23	14730.280	48.457	.000
Intercept	6201426.002	1	6201426.002	20400.266	.000
Thread brand	143624.602	1	143624.602	472.469	.000
Stitch density	162869.179	2	81434.590	267.888	.000
Wash cycle	3428.073	3	1142.691	3.759	.013
Thread brand * stitch density	14879.029	2	7439.515	24.473	.000
Thread brand * wash cycle	2202.673	3	734.224	2.415	.071
Stitch density * wash cycle	9477.921	6	1579.653	5.196	.000
Thread brand * stitch density * wash cycle	2314.971	6	385.828	1.269	.279
Error	29182.800	96	303.988		
Total	6569405.250	120			
Corrected Total	367979.248	119			

a. R Squared = .921 (Adjusted R Squared = .902)

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Tests of Between-Subjects Effects

Dependent Variable: Seam elongation warp

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4908.113[a]	23	213.396	14.210	.000
Intercept	173711.949	1	173711.949	11567.032	.000
Thread brand	314.798	1	314.798	20.962	.000
Stitch density	3212.068	2	1606.034	106.942	.000
Wash cycle	636.945	3	212.315	14.138	.000
Thread brand * stitch density	10.563	2	5.281	.352	.704
Thread brand * wash cycle	34.744	3	11.581	.771	.513
Stitch density * wash cycle	579.581	6	96.597	6.432	.000
Thread brand * stitch density * wash cycle	119.413	6	19.902	1.325	.253
Error	1441.714	96	15.018		
Total	180061.775	120			
Corrected Total	6349.826	119			

a. R Squared = .773 (Adjusted R Squared = .719)

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Tests of Between-Subjects Effects

Dependent Variable: Seam elongation weft

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3949.063[a]	23	171.698	34.129	.000
Intercept	63346.211	1	63346.211	12591.655	.000
Thread brand	878.097	1	878.097	174.544	.000
Stitch density	2334.507	2	1167.253	232.021	.000
Wash cycle	3.564	3	1.188	.236	.871
Thread brand * stitch density	626.178	2	313.089	62.234	.000
Thread brand * wash cycle	27.266	3	9.089	1.807	.151
Stitch density * wash cycle	69.810	6	11.635	2.313	.040
Thread brand * stitch density * wash cycle	9.640	6	1.607	.319	.925
Error	482.958	96	5.031		
Total	67778.232	120			
Corrected Total	4432.021	119			

a. R Squared = .891 (Adjusted R Squared = .865)

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Tests of Between-Subjects Effects

Dependent Variable: Seam efficiency warp

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9505.751[a]	23	413.294	7.064	.000
Intercept	357210.867	1	357210.867	6105.044	.000
Thread brand	1823.640	1	1823.640	31.168	.000
Stitch density	4941.862	2	2470.931	42.230	.000
Wash cycle	1061.684	3	353.895	6.048	.001
Thread brand * stitch density	181.721	2	90.860	1.553	.217
Thread brand * wash cycle	397.881	3	132.627	2.267	.086
Stitch density * wash cycle	840.120	6	140.020	2.393	.034
Thread brand * stitch density * wash cycle	258.843	6	43.140	.737	.621
Error	5617.034	96	58.511		
Total	372333.653	120			
Corrected Total	15122.786	119			

a. R Squared = .629 (Adjusted R Squared = .540)

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Tests of Between-Subjects Effects

Dependent Variable: Seam efficiency weft

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20205.557[a]	23	878.502	51.431	.000
Intercept	337970.988	1	337970.988	19786.322	.000
Thread brand	7931.628	1	7931.628	464.353	.000
Stitch density	8977.416	2	4488.708	262.789	.000
Wash cycle	1427.193	3	475.731	27.851	.000
Thread brand * stitch density	837.096	2	418.548	24.504	.000
Thread brand * wash cycle	171.846	3	57.282	3.354	.022
Stitch density * wash cycle	695.376	6	115.896	6.785	.000
Thread brand * stitch density * wash cycle	165.002	6	27.500	1.610	.153
Error	1639.780	96	17.081		
Total	359816.325	120			
Corrected Total	21845.337	119			

a. R Squared = .925 (Adjusted R Squared = .907)