UNIVERSITY OF CAPE COAST

PERFORMANCE CHARACTERISTICS OF TWO POLYESTER POPLIN LINING FABRICS SOLD ON THE GHANAIAN MARKET

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BY

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Thesis submitted to the Department of Vocational and Technical Education, Faculty of Science and Technology Education of the College of Education Studies, University of Cape Coast, in partial fulfilment of the requirements for award of Master of Philosophy degree in Home Economics

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature…………………….. Date……………..………

Name……………………………………………………………………

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines of supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature…………………. Date……………………..

Name……………………………………………………………………

Co-Supervisor's Signature…………..…………….. Date……………………..

Name……………………………………………………………………

ABSTRACT

This study investigated the influence of laundering and stitch density, on fabric and seam strength, elongation and efficiency of plain seams, in two types of polyester poplin linings sold on the Ghanaian market. To accomplish this, experimental quantitative design was employed for the study. Two types of lining fabrics (Kell Star and Kell Special), two ranges of stitch density (12 and 15 SPI) and three cycles of washing were used to carry out the investigation. A total number of 135 specimens each from the two fabrics were obtained for the study. The specimens were stitched with the Ankerette® electric sewing machine and washed at a temperature of 60°C for 30 minutes with the Standard Launder-Ometer (Gyrowash 315). After drying, the tensile strength and elongation of the specimens were tested with the Universal Tensile Tester (MARK-10) at a rate of 25mm/min. Descriptive statistics (means, standard deviations) and inferential statistics (independent sample t – test, one way ANOVA) were used to analyze the data. The findings revealed that with regards to the seam strength, fabric types, stitch densities and washing did not have a statistically significant difference. There was a statistically significant difference however, between fabric types and stitch densities with regard to the seam efficiency but washing showed no statistically significant difference with regard to the seam efficiency. The results also showed that with regards to the seam elongation, a statistically significant difference was found only with stitch densities but not with the fabric types and washing. It was recommended that dressmakers should be educated through outreach programmes to use appropriate stitch densities in the construction of garments.

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DEDICATION

To my parents; Mr. David Quarcoo and Mrs Faustina Quarcoo

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CHAPTER ONE

INTRODUCTION

Background to the Study

In the construction of clothing, several layers of fabric may be used. The fabrics used come in diverse weights and fabrications and therefore require that these factors be considered in garment making. The fabric which is seen on the outside is the fashion fabric. Every other fabric on the inside is referred to as underlying fabric. Underlining and lining are the most common underlying fabrics that are seamed. Underlining's are made from separate layers joined to the wrong side of the corresponding fashion fabric, and then treated as one throughout the production of a garment, while linings are assembled separately from the fashion fabric and joined at facing or hem areas either with the hand or machine (Griepentrog, 2010).

Fabrics are joined using a variety of ways which include sewing, thermally bonding, etc. (LaPere, 2006). The main process in garment assembly as stated by Carr and Latham in Tyler (2000) is sewing, which is one of the best ways of achieving strength and flexibility in the seam as well as flexibility of the manufacturing method. According to Tyler, much of the application of technology to clothing manufacture is concerned with the achievement of satisfactorily sewn seams. Garment shaping and fitting requires that two or more pieces of fabric be joined with a seam. Various types of fabrics and designs require different seams and seam techniques. The seam provides for the fit and the silhouette of the garment. Almost all of the major categories of apparel structures relate in some way to seams for determining their characteristics. Pockets, sleeves, waistbands and neckline treatments, for example, cannot be successful if the seams that are used to create them are of the wrong type, finished incorrectly, and/or made unskilfully (Stamper, Sharp & Donnel, 1988).

Basically, a seam is the assembly of two or more layers of fabric, leather, or other materials held with stitches. This actually formed the crux behind the British Standard definition of seams as contained in the 1965 version of BS 3870. The current BS 3870 of 1991, and the earlier 1983 edition, define a seam as the application of a series of stitches or stitch types to one or several thicknesses of material (Tyler, 2009). Seams are the basic element or structure of any apparel, home furnishing product and industrial textiles (LaPere, 2006). Seams should be as flat and unnoticed as possible, except those that are used for decorative purposes for garment design and line.

In clothing construction, seams are classified by their type (plain, lapped, abutted, or French seams (Schaeffer, 2011), and position in the finished garment (centre back seam, inseam, and side seam). Because seams are one of the basic requirements in the construction of apparel, seam quality has great significance in apparel products quality. Consumers evaluate seam quality mainly based on the appearance of the seam and its durability after wear and care procedures. The quality of a seam has to be evaluated by the manufacturers during product development and production (Mandal, 2008).

As indicated by Sarhan (2013), a number of previous studies (Behera, Shakun, Surabhi, & Choudhary, 2000; Mukhopadhyay, Sikka, & Karmaker, 2004) have shown that the appearance and performance of seams hinge on the interrelatedness of threads, fabrics, the seam and stitch selection, and conditions used in sewing, which include the stitch density, needle size, correct operation and maintenance of the sewing machines etc. The combination of materials that are assembled with the sewing thread and sewing conditions vary from one dressmaker to the other.

The five major contributors to seam strength include; fabric type and weight; thread type and size; stitch and seam construction; stitches per inch and stitch balance. According to Bharani, Shiyamaladevi and Gowda (2012), garment longevity depends on the seam parameters such as seam strength, seam slippage, seam puckering and seam severance. The fabric properties which affect the seam quality of apparel are cover factor, weight, thickness, strength, shrinkage, functional finishes, extensibility, bending rigidity, and shear rigidity, some of which form an integral part of low stress mechanical properties. Fabric thickness is measured in millimetres and also has an effect on seam efficiency, seam puckering and seam slippage (Gupta, Leek, Baker, Buchanan, & Little, 1992; Behara & Sharma, 1998; Mukhopadhyay, Sikka, & Karmaker, 2004).

Seam slippage is one of the causes of seam failure that affects appearance and performance of the garment. It is the pulling away or separation of the fabric at the seam, causing gaps or holes to develop. This occurs on woven fabric, when yarns slide together along other yarns or a line of stitching. The occurrence of seam slippage is as a result of improper stitch and seam selection, low stitch count or insufficient tension on threads (Sarkar, 2011). Sarkar further explains that seams that are parallel to the warp, as well as fabrics that have filament yarns, low counts and unbalanced weave are more apt to slippage. Stitch type and size, seam type and size, tension, thread used for sewing and excessive use of fabric lubricant - which makes the fabric yarns to be more slippery and also reduces the tensile strength of the fabric, may also have an effect on slippage of seams (Khan, Ahmed, Barder, Shaikh & Kundu, 2013).

Brown and Rice (1998) cited in Chowdhary & Poynor, (2006) indicated that the type of fabric and its weight play a major role in determining stitch density. They proposed stitch densities of 15 - 18 stitch per inch (SPI) to be used for lightweight and woven fabrics, 12-14 SPI for medium weight fabrics and 6-10 SPI for heavy-weight fabrics. Stamper, Sharp, and Donnel, (1988) also asserted that fabrics which are thin and light-weight with a high yarn count should use 15 SPI while heavy and coarse fabrics with low yarn count should employ longer stitches of 8-10 SPI.

Consumers assess seam quality mainly based on the seam appearance and its durability after wear and care procedures. Although seam damage often shows after the garment has been worn, often posing a serious cost problem, the quality of a seam as much as possible should be evaluated by the manufacturers during products development and production (Mandal, 2008). Experience has demonstrated that the strength of many woven fabrics is considerably reduced by the sewing operation. Also, if the seam efficiency ratio falls below 80%, the fabric experiences excessive seam damage by sewing operation. Care should therefore be taken so as to realise efficient seams in garment construction. The possibility of having a flawless seam can be achieved when the sewing parameters are coordinated with thread and fabric properties (Bharani & Gowda, 2012).

In order to produce garments of a particular quality, manufacturers establish seam quality standards. Nonetheless, it is not mandatory for all garments to have the highest quality of seams, but should be of an appropriate quality that can offer satisfactory performance to guarantee serviceability in use and to provide an appearance which is saleable. For this reason, carefully planned steps should be adopted in the manufacture of garments so that the quality of seams truly meets requirements of each type of garment (Mandal, 2008).

Fabric quality is related to physical property and performance features. The fibre content influences the overall characteristics of a fabric. Understanding the components of the fabric and the quality of the seam will ensure the best performance for that particular product. The thorough knowledge of the variables that contribute to better seam performance can only be established through testing (AMANN Inc., 2017).

Statement of the Problem

In Ghana, most custom made garments are either lined or underlined with polyester poplin lining; a lining produced and supplied chiefly from China. There are numerous studies (Gupta et al., 1992; Carr & Latham, 1994; Tarafdar, Kannakar & Mondol, 2007; Danquah, 2010) on seam quality. However, the focuses of these studies were on the seam defects such as the seam puckering (Gupta et al., 1992; Tarafdar, Kannakar & Mondol, 2007), seam damage (Carr & Latham, 1994) and type of thread used (Danquah, 2010). A similar study conducted by Francis-Eshun (2013) was on the seam performance of lined and unlined real wax cotton print, where the polyester poplin fabric was used as an underlining. However, the extensive review of literature has not come across any study on the seam performance of polyester poplin used as a hanging lining by garment manufacturers in Ghana particularly, hence the need for this study.

Pilot queries revealed that majority of dressmakers in Ghana use the same stitch density for sewing both the garment fabric and the lining fabric without any consideration as to the difference in fibre composition and performance of both fabrics. In view of the fact that a lining should be able to last as long as the garment fabric it is used to line, the present study seeks to find out the tensile properties of two types of lining on the Ghanaian market, as well as find out the performance of the seams in these linings.

Danquah (2010), investigated seam performance in wax prints. Although wax prints are made of cotton, when sewn into the traditional attire of "slit and kaba" it is either lined or underlined with polyester poplin. The study focused on the performance properties of two types of polyester poplin commonly used as lining in Ghana.

Purpose of the Study

The purpose of this study was to investigate the influence of laundering and stitch density, on fabric and seam strength, elongation and efficiency of plain seams, in two types of polyester poplin linings sold on the Ghanaian market.

Research Questions

The following research questions guided the study

1. What are the fabric performance quality levels (yarn count, weight) of the two types of polyester poplin linings?
2. What is the seam strength of polyester poplin lining when stitched with "OK" polyester sewing thread at 12 and 15 SPI?

3. What is the difference between fabric strength and seam strength after three washing cycles for the two types of polyester poplin lining?
4. What is the difference between fabric elongation and seam elongation after three washing cycles for the two polyester poplin lining types?

Research Hypotheses

$H_0$1: There is no significant difference between the fabric types with regard to seam strength of a plain seam in a polyester poplin lining fabric.

$H_0$2: There is no significant difference between the stitch densities with regard to seam strength of a plain seam in a polyester poplin lining fabric.

$H_0$3: There is no significant difference between the washing cycles with regard to seam strength of a plain seam in a polyester poplin lining fabric.

$H_0$4: There is no significant difference between the fabric types with regard to seam efficiency of a plain seam in a polyester poplin lining fabric.

$H_0$5: There is no significant difference between the stitch densities with regard to seam efficiency of a plain seam in a polyester poplin lining fabric.

$H_0$6: There is no significant difference between the washing cycles with regard to seam efficiency of a plain seam in a polyester poplin lining fabric.

$H_0$7: There is no significant difference between the fabric types with regard to seam elongation of a plain seam in a polyester poplin lining fabric.

$H_0$8: There is no significant difference between the stitch densities with regard to seam elongation of a plain seam in a polyester poplin lining fabric.

$H_0$9: There is no significant difference between the washing cycles with regard to seam elongation of a plain seam in a polyester poplin lining fabric.

Significance of the Study

Knowing that the performance of fabrics varies, garment manufacturers would want to achieve the best results and make informed choices in terms of seam performance and fabric quality of the fabric they choose as lining for a particular garment. The findings of this study could help clothing manufacturers to assess fabric and seam quality in a more efficient way, particularly in selecting sewing thread and stitch density for a particular type of polyester poplin lining fabric. In turn, this would aid garment engineers in production, planning and quality control. Mehta and Bhardwaj (1998) stated that quality garments must perform satisfactorily in normal use, which presupposes that a garment should be able to survive daily wear and care without seams coming apart, colour fading and fabric tearing. The results of the study provides literature for teaching and further research works on the performance of seams in polyester poplin linings on the Ghanaian market. The study also provides documentation on the influence that variations of laundering and stitch density have on fabric and seam quality of two types of polyester linings on the Ghanaian market which will aid dressmakers in choosing the appropriate stitch densities when sewing.

Delimitations

The scope of this study covered two types of polyester poplin fabrics used as lining in Ghana. Two ranges of stitch densities were employed, specimens were also subjected to three washing cycles and seam quality in terms of strength, efficiency and elongation were tested for.

Limitations

The limitations of the study relate to the environment during testing. Specimens were not dried on the same day and as a result internal validity might be compromised since there could have been a variation of the intensity of sunlight used in drying test specimens.

Again, generalization of the findings will have limitations in that, only one type of thread and two types of polyester poplin lining out of the several types on the market were employed for the study. This therefore limits the prospect of generalizing the research findings to all polyester poplin lining fabrics when used as lining.

Definition of Terms

Seam - a line where two pieces of fabric are sewn together in a garment or other article.

Fabric - cloth produced by weaving or knitting textile fibres.

Clothing - refers generally to fibres and materials which are worn to cover parts of the human body. These include; underwear, shorts, shirts, dresses, coats and pants.

Sewability - a fabric is considered sewable when a seam can be made of the fabric and this seam will display high seam efficiency. It also connotes a fabric which can be seamed without causing undue sewing thread breakage.

Give – the ability of a fabric to stretch

Organization of the Study

The study is divided into five chapters. The first chapter gives background information and briefly introduces the study. Chapter two reviews literature relevant to the study. In the third chapter the methods that were used for the study, which includes the research design, materials, instruments, specimen and specimen preparation, data collection procedures and the data analysis plan were all discussed. The fourth chapter presents the findings and discusses the results of the study. And finally, chapter five provides the summary of the study, conclusions and recommendations.

Chapter Summary

The chapter was an introduction to the thesis which focused on the background to the study, stated the problem and outlined the research questions as well as hypothesis that guided the research. It also stated the significance, limitations and delimitations of the study, and showed the outline or organisation of the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The goal of the research was to investigate the influence of stitch density, fabric type and washing on seam strength, elongation and efficiency of plain seams, in two types of polyester poplin fabrics used as lining in Ghanaian made clothing. This chapter reviewed related literature on the factors and properties that aid in the achievement of quality in seams. Literature was reviewed in the following areas:

1. Theoretical framework
2. Conceptual base of the study
3. Linings and types of linings
4. Seams and types of seams
5. Seam performance characteristics
6. Factors affecting seam quality
7. Tensile testing

Theoretical Framework

Deformation of fabric and seam

The occurrence of fabric deformation can be observed not only as a result of the type of fabric, the raw material, geometric and constructive parameters, but also due to the conditions that the fabric is exposed to, under the action of tensile force; that is, the size of force, time, velocity of acting and so on (Nikolic & Mihailovic, 1996).

This research was aimed at finding out the performance of two types of polyester poplin fabrics which are used as lining in Ghana, after they have been stitched with two different stitch densities and undergone three washing cycles. Any form of change in the tensile behaviour of the fabrics can be attributed to the fabric, sewing thread, number of layers of fabric, shape and size of sewing needle, type of stitch and its density, seam type and seam allowance.

a. fabric

In the process of sewing, the fabric properties (weave, thickness, composition and strength) determine how it should be sewn, as well as its seam performance (Sauri, Manich, Lloria, & Barella, (1987). The fabric goes through different mechanical actions - shear, compression, extension (Postle, 1998; Mahar, Ajiki, & Postel, 1989) - which determine the performance of the seam and finished garment. Deformation of a sewn fabric is as a result of the internal abrasions of fabric and of its relaxation process after sewing (Tartilaite & Vobolis, 2001b). The stability of stitches in apparel is reliant on the rigidity of the fabric (Tartilaite & Vobolis, 2001a). According to Lindberg, Westerberg, and Svenson (1960), the bending property of fabric is also a significant factor which has an effect in the puckering of seams.

Fabrics come in different weaves, one of which is the plain weave - also called tabby weave, linen weave or taffeta weave. The plain weave is one of the most basic of the three fundamental types of textile weaves (Kadolph, 2007). It is a strong and durable weave used for fashion and furnishing fabrics. A criss-cross pattern is formed by aligning the warp and weft yarns. Plain weaves usually employ half the number of picks per inch for the number of ends per inch. Nonetheless, the balanced plain weave is made with threads of the same number of ends per inch as picks per inch, all of the same weight for both the warp and weft directions (Kadolph, 2007).

b. sewing thread

The use of a suitable sewing thread is important in ensuring the desired end result in the construction of garments and other articles. The properties of a sewing thread (its tensile performance, compactness, heat-resistance and abrasion resistance) however, are given by its structural parameters (thread type, twist, size). In reality, the type of thread determines the severity of abrasion (yarn-metal friction) which is central for seam durability. Furthermore, during sewing, the elongation and toughness of the thread reduces considerably. According to Sundaresan, Hari and Salhotra (1997), polyester threads have a lower rate of strength loss as compared to cotton threads. The fineness of thread is expected to affect the strength of seam: thicker threads provide better seam strength; nonetheless, it requires the use of a thicker needle which may damage the fabric.

c. number of layers of fabric

When there is an increase in the number of layers of fabric, it is expected that the join becomes stronger. But on the contrary, the strength of sewing thread used is reduced due to the thread suffering a higher coefficient of friction (Sundaresan, Hari & Salhotra, 1998).

d. shape and size of sewing needle

The structure of a fabric can be damaged when the fabric is penetrated by a blunt or oversized needle. The needle can penetrate at any point in the fabric and distort the fabric loops, thereby cause fabric damage. The choice of the right needle size and point is crucial to ensure quality seams. Fabric characteristics (tightness, weight and number of layers) and sewing thread properties (fibre type and fineness) are however two important factors affecting the selection of the right needle (Gribaa, Amar & Dogui, 2006).

e. type of stitch and its density

A wide variety of stitches are used depending on the function of the seam and its placement in the clothing item being made. The strength of a sewn fabric and its elongation can be affected by any change in the form of seam because of the difference in the interlacement of thread with fabric for each stitch type. The choice of the most suitable stitch density depends on the material to be sewn and the desired seam properties. Very high stitch densities do not always give good results; they may be associated with risks of damage of the structure of the fabric and may also result in puckered seams (Gribaa, Amar & Dogui, 2006).

f. seam type and seam allowance

Seam type affects the quality and appearance of garments. The type of seam selected should be selected according to the garment and fabric type (Gurarda, 2019). Loosely woven fabrics tend to slip at stressed seams (Schaeffer, 2008). The amount of seam allowance given can result in the pulling out (seam slippage) of yarns in a seam. In order to abate the slippage of seams the amount of allowance used must be regulated. However, the fabric properties such as smoothness and type of filaments, sewing thread and the stitch parameters must be taken into account (Gribaa, Amar & Dogui, 2006).

Conceptual Base of the Study

The quality of a garment is determined not only by fabric quality but also the ease with which a shell structure can be produced with the fabric.

When an increasing force is applied at right angles to the seam line of the joint of two pieces of woven fabric, rupture eventually occurs at or near the seam line usually at a load which is less than what is required to break the unsewn fabric. Seam characteristic parameters are seam strength, seam pucker, seam stiffness, seam appearance and seam efficiency (Dobilaite & Juciene, 2006; Brain, 1970).

Many researchers (Tarafdar, Kannakar, & Mondol, 2007; Meric & Durmaz, 2005), have established that there are various factors which affect the quality of seams. These comprise sewing thread, sewing conditions, care procedures such as laundry and others. The quality of seams is of great importance in the production of garments. Consumers evaluate seam quality mainly based on the appearance of the seam and its durability after wear and care procedures. Various types of seams and stitches can be applied on finished fabrics (garments) with different stitch densities (SPI) having diverse effects on seam strength, quality and performance. This is illustrated in the Figure 1.

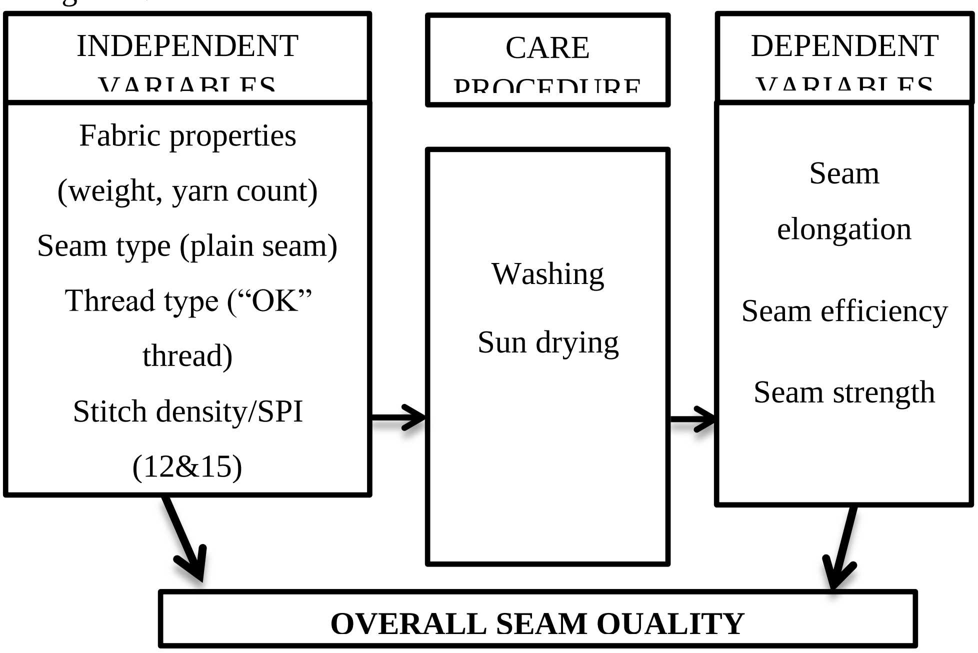

Figure 1: Conceptual Framework, Source - Researcher's own construct

Interpretation of framework

In the quest for achieving the purpose of the study, a conceptual framework was constructed to serve as a guide to the study. From Figure 1, independent variables such as fabric type, stitch density, thread type go through care procedures which determine the seam elongation, efficiency and strength (dependent variables). Both the dependent and independent variables are able to predict the overall seam quality.

Linings and types of linings

A diverse range of fabrics are used inside garments in order to add support to the fashion fabric or to hide inner construction details, so that the garment wears better, holds its shape, and is more comfortable. These fabrics include interfacing, lining, underlining (sometimes referred to as interlining) and batting. Many different types of fabric can be used to perform these functions and not only those made purposely to be used as lining (Fresia, 2010).

Linings, underlinings, and interlinings serve different purposes in a garment and are made up of different fabrics added to the inner part of a garment. A lining is handled like a second garment, thus it is assembled separately and finally attached to the edges of the fashion fabric with the wrong sides facing each other leaving the inside of garments with a neat finish (Griepentrog, 2010).

Linings are the functional parts of the garment, being used to maintain the shape of the garment, to improve the hang and comfort by allowing it to slide over other garments, to add insulation and to cover the inside of the garment of complex construction, to make it neat (Pamuk, Kurtoglu, Tama, & Ondogan, 2011)

Linings are a must for some types of garments, but not all of them. Items that should be lined include anything that is very constructed or tailored, expensive to clean or delicate, lighter see-through fabrics, jackets, coats, structured dresses, loosely woven fabrics, suede's and leathers as well as knits and tailored skirts (Into mind, 2014b).

A lining fabric should be assessed like any other fabric and must feel good on the skin. In general, linings should be made from a thicker, sturdier material that is antistatic. Whether cotton, satin or a wool mix, it is up to the designer to always make sure that the lining has the same care code as the fashion fabric, otherwise getting it cleaned is going to be very difficult (Into Mind, 2014a).

In other garments, a lining, while not showing, will always add a feeling of luxury. It will also add comfort, if the fashion fabric is even slightly rough to the touch. It may make wearing a slip unnecessary. In a straight skirt or pants, a lining will prevent bagginess at the seat and knees. A skirt is sometimes lined to just below the seat to prevent stretching and wrinkling. If made a little bit smaller than the garment, a lining will help preserve a garment's shape. However, since it is not caught in the seams, it cannot contribute to the shaping itself. And if the fashion fabric needs more body, an underlining is used, which as a backing for the fashion fabric, is stitched into the garment seams.

A lining hides the interior construction of a garment. It reduces the transparency of the fashion fabric, increases the life of the garment, and makes it more comfortable and easier to wear. Linings should be chosen based on the compatibility with the fashion fabric in weight and care requirements. A lining fabric should be slippery, flexible, colourfast, durable, wrinkle resistant and comfortable to wear (Fresia, 2010).

lining fabrics

Fabrics used for lining may or may not be made especially for the purpose. Many dress fabrics that imitate silk-crepe, taffeta, satin and tricot also make beautiful linings. To be suitable, a fabric should be smooth to the touch, soft, pliable and light enough in weight not to interfere in any way with the hang of the garment fabric. Fibre content and construction may vary (Sew-helpful, 2017).

fabric selection

There are a multitude of fabrics suitable for use as a lining. The deciding factors include:

a. Type of fashion fabric (weight, fibre content/method of care, hand or "feel," personal likes and dislikes)
b. Type and style of garment
c. Type of lining - partial or complete; and how the lining will be attached.

Fabrics may be woven or knit; they should be able to "give" and recover as necessary to accommodate body movement. The lining fabric should be durable, opaque, and colourfast to perspiration and body oils and have the same care method as the fashion fabric. Lining should match or harmonize in colour with the fashion fabric, and have a smooth surface texture to permit the garment to be taken on and off the body easily. It is important that the lining be the same weight (a lightweight polyester or microfiber jacket or dress) or lighter weight (wool slacks or suit) and softer than the fashion fabric so that it does not dominate the garment. Lining fabric should be pre-shrunk before using following the same procedure you plan to use for the finished garment (Heaton, 2001).

types of lining

Most traditional lining fabrics are light weight and silky or slippery, but other types of fabrics can be used as lining depending on the requirements of the garment. Natural fibres and man-made fibres with a natural base, like rayon, absorb moisture more readily than synthetic types, meaning they wrinkle more but are often more comfortable to wear.

Poplin – Poplin, also referred to as tabbinet, is a strong fabric in a plain weave of any fibre or blend, with crosswise ribs that typically gives a corded surface (Thames & Hudson, 2007). Poplin was originally made up of a silk warp with a weft of worsted yarn. Poplin is now made with cotton, wool, polyester, rayon, silk or a mixture of these, with a plain over/ under weave. If the weft and warp threads are therefore of the same material and size, the effect is a plain woven surface with no ribbing. Shirts made from this material are easy to iron and do not easily wrinkle.

The term poplin was coined from papelino in the 15th century from a fabric made at Avignon, France. It was named for the pope's residence and from the French papelaine; a fabric normally made with silk of the same period (Callan & Glover, 2008). Until about the 20th century, poplin was used primarily to make silk, cotton or heavy weight wool dresses, suitable for winter wear.

British-made cotton poplin was introduced to the United States in the early 1920s. However, the American market renamed it broadcloth (a name that is still in use for a cotton or polyester-cotton blend fabric used for shirting) because they thought that the name had connotations of heaviness (Tortora & Ingrid, 2014). Poplin fabric is a durable medium weight fabric that has a very fine ribbed effect. It usually comes in cotton or cotton/polyester blend and it is perfect for making shirts, dresses, skirts, light weight jackets, among others.

Polyester – in all ready to wear clothes polyester lining is the most often used lining material because it is inexpensive. It is a shiny synthetic fabric which is very easy to care for. These linings are washable and available in various weights and weaves. Unlike acetates, they take stress very well. Polyester traps moisture near the skin, however, it can feel hot and sticky or clammy in some situations (Sew Guide, 2019).

lining weights

In general the weight of linings is described in terms of grams per square metre (GSM) or thread count (number of threads per square inch of fabric). A high thread count or "GSM" indicates a denser and heavier lining, often with a better drape and less translucence (Sew- Helpful, 2017).

A lightweight fabric is typically between 30-150 GSM, medium weight 150-350 GSM, and heavy weight 350+ GSM (http://blog.fabricuk.com/understanding-fabric-weight/). To determine the best lining weight for a garment, first the amount of structure and warmth desired must be considered. Then the lining and fashion fabric can be layered on the hand to test compatibility.

Lightweight

Among the lightweight linings, China silk is considered as the lightest. It is the best choice for delicate blouses, soft skirts, jackets, dresses and pants. Another lightweight choice that provides a little more structure is Silk charmeuse (Bolton, 2009).

Medium weight

These linings include broadcloth, as well as jacquard, silk taffeta, and most polyester linings. Bemberg™ rayons commonly fall under this category although they are available in many weights (Bolton, 2009).

Coat weight

Linings which are a perfect choice for outer wear include silk satin, acetate satin, polyester satin and acetate twills which have a dense weave, making them heavy, durable and warm. There is also a water-repellent acetate overcoat lining for trenches and rainwear (Bolton, 2009).

Heavy weight

Most heavy weight quilted lining are made from acetate of polyester which is durable but bulky and requires dry cleaning. They offer the warmest linings for coats since they trap air in the batting. Another heavy weight lining is the flannel-backed lining (also called fleece-backed lining). These linings are the stiffest choice but have a silky side which enable them to slip over clothes easily. They also provide just about the same warmth as the quilted lining but without bulk. It is also acetate and requires dry cleaning (Bolton, 2009).

Seams and types of seams

In sewing, a seam is defined as a juncture at which two or more planar structures, such as textile fabrics, are joined by sewing, usually near the edge (Gurarda, 2019).

types of seams

The type of seam that is chosen for a garment is dependent on convenience in assemble in relation to the machinery available, the aesthetic standards, comfort in wear, cost, strength and durability (Tyler, 2000). Schaeffer (2011) stated that, all basic seams used in garment construction are variants of four basic types of seams, namely; plain seam, French seam, flat or abutted seam and lapped seam. However, stitched seams have been divided into eight classes by the British Standard according to the minimum number of parts (main fabrics of the garment or some additional item such as a lace braid or elastic) that a seam is made up of; including some where only one piece of fabric is involved. Examples include a raw edge which has been neatened by means of stitches and the hem of a garment folded up on itself. This alters the traditional notion that a seam is a joint between fabrics (Carr & Latham, 1994).

For each of the hundreds of different seam types, an identifying numerical designation composed of five digits has been given by the British Standard, which identifies what it depicts. The first digit represents the seam class (1-8). The second and third are counting numbers (0-99) which represent the differences in the location of the needle penetrations. The designation of the stitch type has to be added after the designation of the stitched seam, for the seam specification to be meaningful (Tyler, 2000).

The 1965 British Standard included six seam classes which usefully describe their constructions. Two more classes were added with the 1983 edition giving a total of eight classes which remained the same till date. Following are a variety of seams together with their descriptions as indicated.

1. Class 1 - Superimposed seam
2. Class 2 - Lapped seam
3. Class 3 - Bound seams
4. Class 4 - Flat seams
5. Class 5 - Decorative / Ornamental stitching
6. Class 6 - Edge finishing / neatening
7. Class 7 - Attaching of separate items
8. Class 8 - Single ply construction

Seam performance characteristics

There are several factors involved in determining the quality of a seam. Essentially these factors can be divided into two main groups. The first group is reliant on sewing parameters itself which include the threads used, needle size, stitch types and densities and also sewing machine settings such as speed and tension. The second group is the fabric mechanical properties (Mandal, 2008). Studies by Bhalerao, Budke and Borkar, 1997; Behara, Chand, Singh and Rathee, 1997a; Behera, Shakun, and Choudhary, 2000; Mukkhopadhyay, Sikka and Karmakar, 2004, also showed that seam appearance and performance depend on the interrelationship of fabrics, threads, stitch and seam selection, (which accounts for seam strength, seam slippage, seam puckering, seam appearance and yarn severance), as well as sewing conditions, (which include the needle size, stitch density, the appropriate operation and maintenance of the sewing machines etc). Fabric construction, needle thickness, chemical treatments of fabric, and sewing machine settings with sewing thread, are the most important factors that have an influence on the tendency for seam damage. The construction of yarn, fibre content, tightness and density are important parameters for fabric construction on seam damage.

Manufacturers establish seam quality standards that result in garments of a particular quality level. Not all apparel products need to have the highest seam quality, but the seams should be of the appropriate quality that could provide adequate performance to ensure serviceability in use and to provide a saleable appearance (Mandal, 2008). In general, the seam quality mainly depends on the strength and the appearance of the seam itself. The strength and appearance of a seam affects both the aesthetic and functional performance of a garment and is important to its durability and saleability. A seam of good quality should be flexible and strong with no defects such as puckering or skipped stitches; and the overall appearance of the seam should meet the design requirements of the garment (Mandal, 2008).

thread

Sewing threads are exceptional types of yarns designed and engineered to swiftly pass through a sewing machine, proficiently form a stitch, and function while in a sewn product without breaking or becoming distorted for at least the useful life of the product (Pizzuto 2005). All threads need to be twisted to ply two or more threads together. To ensure that thread does not snarl during sewing at very high speed single threads are usually twisted in an ‘S’ direction and then plied and twisted in a ‘Z’ direction (Ukpanmwan, Mukhopadhyay & Chatterjee, 2000). The mechanical properties of sewing threads play an important role in determining the quality of sewn fabric where the selection of sewing thread is based on the performance during sewing and also during wear and cleaning of the garments (Mori & Niwa 1994). Improper selection of sewing thread affects sewability. Sewability is the condition where the thread can work efficiently with the sewing machine (Kropf, 1960). Improper selection of sewing threads will also lead to a poor seam performance and aesthetics value and in turn increase costs for re-stitching and other making-up processes. There are a variety of sewing threads available, varying by fibre type, construction and finishes which influence the appearance and performance of the thread. A high quality sewing thread has a uniform diameter and can be sewn on various types of fabrics and sewing machines (Glock & Kunz, 1995). Sewing threads for garments are usually made from 100% cotton, 100% spun polyester, 100% polyester core-spun, continuous-filament polyester, and also combinations of both.

Different woven fabric will provide different effects on seam quality when different sewing threads are used. A definite effect will be evident with the seam strength and appearance due to the different sewing parameters which include; the thread type, size and finish (Glock & Kunz, 1995; Rengasamy Kothari, Alagirusamy & Modi, 2003; Gribaa, Amar & Dogui, 2006). The expectation on seam quality for various apparel products will also be different. For example, sportswear focuses on seam performance, whereas shirts and night gowns focus more on seam appearance (Mandal, 2008). One essential requirement of any thread is that it must be compatible with the needle size, various sewing machine settings (sewing speed, thread tension) and the fabric on which it is being sewn. Obviously the stronger the sewing thread, the stronger the seam. Higher number of stitches per inch up to a point will give higher seam strength, but too many stitches per inch will weaken the fabric, making the seam stay intact, but the fabric ruptures resulting in seam failure. High seam strength will also be evident with a high thread tension but when the thread tension is too high it will result in seam puckering (Seetharam & Nagarajan, 2014). It can be summarized that thread with a good strength and elongation and good recovery behaviour combined with a correct thread size and sewing machine setting sewn to appropriate fabric can produce a good seam quality.

seam strength

In determining the durability of a garment, seam strength is a very important factor to be considered. The strength of a seam is determined by its resistance to pulling force and abrasion (Seetharam & Nagarajan, 2014). Some types of garments such as jeans require a seam with more prominent design, while other garments such as the dress shirt conventionally require the seams be sewn more inconspicuously (Mandal, 2008). The seam boldness is an important element of determining the seam appearance and the size of sewing thread becomes the primary factor for the manufacturers to consider for the required seam quality. Lap felled seam will be stronger than lapped seam. Fabric with high seam efficiency will provide stronger seams than fabric with low seam efficiency (Seetharam & Nagarajan, 2014). Damage of seams can be a serious cost problem, which often shows only after the garment has been worn.

fabric & needle size

One of the basic elements that directly contribute to the formation of seams is the sewing needle. Different effects with respect to seam strength and garment appearance are produced as a result of the way in which the needle penetrates a fabric during the sewing process (Stjepanovic & Strah 1998). Fundamentally, the function of the needle is to:

1. create a hole in the fabric for the thread to pass through without damaging the fabric;
2. take the needle thread through the fabric and form a loop which can be picked up by the hook on the bobbin case in a lockstitch machine;
3. pass the needle thread through the loop which is formed by the looper mechanism or other mechanism for machines other than lockstitch machines.

Different needle sizes are available so that selection can be made based on the types of material to be sewn and on the size of sewing thread to be used. It is very important to have a correct selection of needle (size and shape) and sewing thread according to the fabric characteristics so that a balanced stitch can be formed reducing stitch damage, puckering and improving seam strength (Gribaa, Amar & Dogui, 2006). Different needle sizes have different effects on sewing performance. A bigger needle size needs more force to push the needle through fabrics. This increases the frictional force between needle and fabric, and this also increases the needle temperature. When sewing man-made fibres especially, increase in needle temperature can reduce the fabric strength. The breakage of sewing thread is also increased with the increasing value of needle temperature because the lubricant evaporates and the fibres suffer damage (Ghani, 2011). Studies also show that small needle size used with coarser thread will cause the thread to have a hairy surface due to abrasion with the needle (Munshi, Pai & Ukidve, 1982). Finer thread shows less damage on the thread surface due to lower friction between thread and needle. Abrasion between thread and needle can be at the good setting by proper selection of thread in terms of fibre types and construction, needle size, sewing machine speed and also stitch densities (Munshi, Pai & Ukidve, 1982).

During sewing, effective factors for seam performance are sewing needle penetration forces and fabric deformation. Seam damage which is as a result of the penetration of needle through a fabric, may affect seam performance. Stiffness of a fabric, yarn and a lack of fabric mobility results in needle cutting and yarn severance. When a needle penetrates a fabric, instead of moving and deforming, the yarn is ruptured or burned (Ghani, 2011).

stitch & stitch density

Besides the seam formation, stitch properties such as size, tension and consistency determine the quality and performance of the sewn fabric (Glock & Kunz, 1995). A stitch is formed when one or more strands or loops of thread intra-loop, inter-loop or pass through fabric resulting in a one unit conformation (BS3870:Part1 1991 in Ghani, 2011). Intra-looping means the passing of a loop of thread through another loop formed by the same thread, inter-looping is defined as the passing of a loop of thread through another loop formed by a different thread and interlacing is the passing of a thread over or around another thread or loop of another thread. There are six classes of stitch, namely Class 100 chain stitches, Class 200 stitches originating as hand stitches, Class 300 lockstitches, Class 400 multi-thread chain stitches, Class

500 over-edge chain stitches and Class 600 covering chain stitches. The most common stitch type used is Class 300. Lockstitches are formed from two or more threads or groups of thread. Loops of one thread or one group are passed through the material and secured by the thread or threads of a second group. The interlacing of thread makes it very secure and difficult to unravel. Lockstitch 301 is the most common stitch in the clothing manufacturing industry and provides a very good strength when used with suitable sewing thread. The number of stitches per cm (spcm) is important in determining the quality of sewn fabric. The spcm is measured by calculating the number of yarn interloops on the surface of the sewn fabric in centimetres. Usually, a fine material uses a higher number of stitches and thick material uses a lower value of spcm. If an incorrect spcm is used, the fabric can have problems in being sewn and this can cause thread breakage and can also initiate seam puckering (Tyler, 2000).

The sewing conditions such as the thread tensions and pressure of presser foot should be adjusted based on the thread size and the material to be sewn. However, the stitch density may vary at different seam locations. Stitch density is a key attribute in the quality of seams, in that it assembles the fabric components. The change of stitch density wields a great influence on seam strength and appearance (Mandal, 2008).

sewing machine setting

The feed mechanism of the sewing machine plays an important role in the process of producing high quality sewn garments. The four-motion drop feed system is the simplest sewing machine which consists of:

1. *The presser foot* which firmly holds the fabric down against the throat plate, thus preventing the fabric from rising or falling with the needle. Simultaneously, it holds the fabric against the teeth of the feed dog as it rises up to transport the fabric.
2. *Throat plate or needle plate* which provides a smooth, flat surface over which the fabric passes as successive stitches are formed.
3. *Feed dog* which moves the fabric along by a predetermined amount and the stitch length is controlled by the stitch length or feed regulator.

All these feed mechanisms must be set so that the feed is suitable for the types of material being sewn in order to reduce damage and stitch failure. Varieties of feed mechanism are available so that correct setting can be made according to weight, thickness and structure of fabric.

fabric mechanical properties with relation to seam quality

A fabric goes through diverse kinds of strain such as tensile, pressure, shear and bending in the construction of fabric into a garment. Different fabrics react differently to strain because textile materials have nonlinear mechanical properties (Pavlinic & Gersak 2003).

extensibility

Extensibility determines the capability of the fabric to be stretched during the making up process of the garments (Ly, Tester, Buckenham, Rocznoik, Adriaansen, Scaysbrook & De Jong, 1991). This is because during the sewing process, fabric needs to be stretched in order to match up with the garment shape. The value of extensibility determines the sewability of the fabric. Some examples of recommended fabric extensibility are:

1. FAST control chart for wool fabrics: minimum limit of 2% for the warp and weft directions and a maximum limit for the warp direction of 4 per cent and 6 per cent for the weft direction (Cheng, How & Yick, 1996);
2. KES control chart for suiting materials with very high wearing comfort: warp direction is 4 to 5% and for weft direction, greater than 10 per cent (Kawabata & Niwa, 1994).

Low values of extensibility can cause seam puckering because the fabric is not easy to mould (Saville, 1999). If the value of extensibility is too high, it can be stretched easily and special attention will need to be given by the workers especially during laying up, cutting and also during the sewing process in order to give control to the fabric (Cheng, How & Yick, 1996, Hui, Chan Yeung & Ng, 2007). Research has proven that seam stability can be established when the fabric is thicker, with greater bending stiffness and extensibility (Amirbayat, 1990; Amirbayat & Norton, 1990; Amirbayat & McLaren, 1991).

bending

Bending properties are related to the drape behaviour of fabric. The bending rigidity is closely related to the stiffness during fabric handling. Bending rigidity measures the resistance of the fabric to being bent. Lightweight fabrics usually have low bending rigidity and this makes it difficult to handle during cutting because of its flexibility and can cause seam puckering. It is recommended that lightweight fabrics should have a minimum value of 5µN.m for warp and weft directions (Cheng, How & Yick, 1996). High bending rigidity fabric is more manageable and can produce a flat seam compared to lightweight fabric (Minazio, 1995; Saville, 1999). But if the value is too high, the fabric is difficult to control during sewing because it is too stiff to react to any manipulation that may need to be done by the sewing operator (Cheng, How & Yick, 1996; Hui, Chan, Yeung, & Ng, 2007). It can be concluded that fabric needs to have a moderate value of bending rigidity in order to be handled easily and produce good seam appearance.

shearing

Shear rigidity is the resistance of components of a fabric to lateral sliding over each other (Taylor, 2004). Shear hysteresis can be defined as 'the force of friction occurring among interlacing points of the system of the warp and weft yarns when they are moving over each other, having their origin in the forces of stretching/shrinking, since the system of warp and weft yarns stretches/shrinks under strain'(Inui & Yamanaka, 1998). For apparel, it determines the ability of the fabric to be stretched and sheared during the transformation of fabric into 3D garment shapes. Depending on the fabric structure, yarn density and cloth cover factor, fabric has different shear hysteresis. It is recommended that lightweight wool suiting fabrics have a minimum limit of shear rigidity at 30 Nm-1 and a maximum limit of 80 Nm-1 (Cheng, How & Yick, 1996). If the shear rigidity is too low, the fabric can easily be distorted and skew during the production of the garment. Low values of shear rigidity have the same effect of high values of extensibility; both give difficulty during production (Saville 1999). Meanwhile, if the fabric has high shear rigidity, it will be difficult to shape and mould during the sewing process (Hui, et al., 2007). Shear deformation is closely related to comfort for the wearer where it is linked with deformation of the fabric due to the movement of the human body (Kawabata & Niwa 1994).

compression and formability

Compression may be defined as a decrease in intrinsic thickness with an appropriate increase in pressure. Intrinsic thickness is the thickness of the space occupied by a fabric subjected to barely perceptible pressure. Meanwhile for modelling and simulation purposes, the compression property can give an indication of the material's springiness. A fabric that compresses easily can be identified as soft material and has a low compression modulus or high compression. Any surface treatment applied to improve the fabric hand, such as singeing or pressing, has an impact on the compressibility property of the fabric (Murthyguru, 2005). The fabrics' buckle during a sewing process is related to compression and formability.

During seam construction, if the fabric has a low formability, it tends to buckle leading to seam pucker occurrence. In contrast, fabric with high formability could minimise seam puckering due to lower thread and needle compression (Boos & Tester 1991; Ly, et. al.; Minazio, 1995). The use of suitable sewing thread, needle size and thread tension are crucial in determining the minimum and maximum limit of fabric formability (Cheng, How & Yick, 1996). The combination of fabric bending and extensibility determines the fabric formability where it can be used to predict the limit of overfeed before the fabric becomes buckled. Fabrics with low formability value suffer puckering problems easily as a result of their reduced ability to react to the compression instigated by the sewing thread during the construction of seams (Ly & DeBeos, 1990).

thread properties and seam performance

Although thread is by no means the only factor which determines the value of the properties of seam strength, elasticity, durability, security and comfort, or helps maintain the special properties of certain fabric types, it is one of the most important ones. The others are the type of stitch, seam, needle and feed mechanism, and the nature of the material being sewn (Carr & Latham, 1994).

seam strength and elongation

Seam strength is an important contributor to seam performance. Due to its importance, lots of studies have been conducted to ascertain seam strength characteristics of some fabrics with some of the factors that contribute to seam strength. The appearance of a garment, its durability and cost is influenced by the stitch density used throughout the garment. American and Efird (2002) indicated that generally high stitch densities produce greater seam strength. However, American and Efird Inc., (2009) noted that on some fabrics (light and medium weight), too many stitches can cause damage to the fabric by cutting the yarns enough to weaken it and excessive stitches per inch can also contribute to seam puckering, and reduce the speed through the machine. Ali, Rehan, Zamir, Hafeezullah, & Ahmer, (2014) found from their experimental results that an increase in stitch density causes an increase in seam strength but up to an extent, because the stitch density after a certain level ruptured the fabric. Chowdhary (2002) reported that antiqued and sandblasted jeans had higher tensile strength and elongation in warp direction than weft direction. For LS401 seams, fabric broke but seam did not. For SS 516, the seam strength was highest for the stone washed jeans followed by antiqued and sandblasted jeans. Chowdhary and Poynor (2006) also found differences in seam strength for three stitch densities in both warp and filling directions. Seam strength increased as stitch density increased. Contrary to the finding of American and Efird Inc. (1997) and Chowdhary and Poynor (2006), Wang, Chan and Hu (n.d) observed changing patterns of vibration cycle of tensile strength extensibility and stress withstand retention 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 reduced. Mukhopadhyay (2008) noted increase in seam strength with increase in linear density of sewing thread.

An increasing force applied at right angles to the join of two pieces of woven fabric eventually results in rupture. This could either be at or near the seam line and at a load usually less than that needed to break the unsewn fabric. All seams are made up of two elements-the fabric and the sewing thread, seam failure is therefore as a result of breakage of either the fabric or the thread or sometimes, both simultaneously (Carr & Latham, 1994).

When a fabric breaks, there are two likely reasons. The fabric may break, on account of being debilitated by needle damage, and the seam will rupture, then again, more common is when the seam opens up as a result of what is termed seam slippage. Seam slippage occurs in fabrics which have been woven from yarns that are slippery, or loosely woven. When a seam is stressed from corner to corner, the yarns parallel to the seam, and within the seam allowance, slide over the yarns which are at right angles to the seam. It is seen on the outside of a garment, close to the area of stress (Carr & Latham, 1994).

The fabric length and elongation of a fabric are an indication of the thread's ability to contribute to seam performance. The fabric strength bears a direct relationship to stitch strength and hence to seam strength. Fabric elongation is an indication of the degree to which a seam, under stress, can be stretched without a thread breaking. The ultimate elongation of a seam is dependent on the fabric being stitched, the stitch and seam type, and number of stitches per inch. In testing fabric strength and elongation, each specimen consists of two pieces of fabric which have been joined by a seam. Both ends of one piece are secured in one clamp of the testing machine so that the length of the fabric is about one-half the guage length (Mehta & Bhardwaj, 1998).

characteristics of apparel strength

ASTM D1683-07 (2007), states that sewn seams in woven fabrics may fail due to rupture, slippage, or any combination thereof. According to ASTM D1683-07 (2007), rupture can be classified as failure of fabric, or sewing thread or seam slippage. The various key properties of apparel strength are pointed out as follows: Fabric strength, Seam strength, Resistance to yarn slippage.

1. Fabric strength:

Fabric strength can be divided into three. That is, resistance to tensile force, resistance to tearing force and resistance to bursting force. Resistance to tensile force and tearing force are normally measured to identify the fabric strength of woven fabrics but with regards to knitted fabrics resistance to bursting force is the measure used to ascertain the fabric strength (Islam 2016, April).

2. Seam strength:

Failure of a seam in apparel may occur due to the failure of the sewing thread thereby leaving the fabric intact or fabric damaged leaving the seam intact or both breaking at the same time. Seam strength is tested in almost the same way as fabric breaking and bursting strength. The strength of a seam or stitching should be equal to or slightly less than the fabric strength (Islam, 2016, April). Stitch type, thread strength, stitch per inch (SPI), thread tension, seam type, seam efficiency of the fabric are important elements which have great influence on the strength of a seams.

3. Resistance to yarn slippage:

Stress on a seam or joint of the apparel may result in seam failure due to the displacement of yarns present in the cut area of fabric after seam line.

seam efficiency

Seam efficiency is a percentage representation of the ratio between the strength of the seam and the fabric (Chowdhary & Poynor, 2006). Chowdhary and Poynor postulated that seam efficiency is a function of compatibility between the fashion fabric, sewing thread, yarn size, needle, tension, seam type, and stitch density. Mehta and Bhardwaj (1998) stated that when woven fabrics are seamed, the absolute seam strength is not, in the majority of cases, of utmost importance, provided it is reasonably high. They concluded that a seam efficiency of about 60-70% indicates the seam will be commercially acceptable. Mehta and Bhardwaj (1998) further indicated that a fabric with higher seam efficiency would provide stronger seams than a fabric with lower seam efficiency. A study by Akter and Khan (2015) on “the effect of stitch types and sewing thread types on seam strength for cotton apparel” revealed that all stitches have higher seam efficiency in the warp direction compared to the weft direction.

ASTM D6193 – 09 (2009) points out that seam efficiency of the sewn seam should be as high as possible so as to produce seam strength with a balanced construction that will withstand the forces encountered during the use of the sewn item. A percentage efficiency of more than 100% is an indication that the seam is stronger than the fabric. If it is less than 100%, the fabric is stronger than the seam (Chowdhary & Poynor, 2006). They further stated that seam efficiency of 100% is required for a perfect seam. Chowdhary and Poynor (2006) observed in their study that seam efficiency differed 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 46.39% in the warp and 40.43% in the weft. They therefore, recommended 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).

effects of laundry on seam performance

Moris and Prata (1977) mentioned that as much as half of the wear on fabrics during use may occur in laundering, abrasion may occur in both washing and in drying. Studies have shown that the type of detergent used, water quality, and drying conditions are imperative variables affecting the deformation of the garment. The resistance of a garment to washing and dry cleaning is a basic factor for evaluating the exploitation properties of seams in apparels (Germanova-Krasteva & Petrov, 2007). Apparels are affected by physical and chemical factors, such as abrasion, chemical products (for example, in laundry) and others during wear and care. As Germanova-Krasteva and Petrov (2007), pointed out, underwear and upper cloths are washed and overcoats proceed through dry-cleaning. Mukhopadhyay, Sikka, & Karmaker, (2004) hypothesised that seam performance after laundry is important to adjudge the suitability of a sewn product.

A study by Shawky (2013), showed that before and after 10 cycles of laundering cotton fabrics, there was a significant difference. Viola and Ahuwan (2015) on the other hand revealed that after four washing cycles, there was no statistically significant difference between washing cycles with regard to plain seams in Nigerian wax print. This clearly indicates that the frequency of laundering has an impact on the fabric or article being laundered.

Mukhopadhyay, Sikka, & Karmaker, (2004) in their study on the impact of laundering on the seam textile properties of suiting fabric noted an interaction of sewing parameters and laundry on the performance of seams. They identified 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 were reduced after laundering; the reduction was greater in polyester-cotton blended fabric. Laundering caused a greater decrease in seam strength and seam efficiency for coarser sewing threads. On the other hand the strain of seams at fracture was increased slightly, although rupture reduced after laundering.

Another study by Mukhopadhyay (2008) on the relative performance of lock stitch and chain stitch at the seat seam of military trouser showed that the force at small strain and force at break increased after laundering. They identified that the change was more in the case of lock stitched fabric stitched with coarser sewing thread. Nonetheless, there was a marginal decrease with regard to strain at break after laundering in the case of both stitches.

Factors affecting seam quality

Seams are formed when fabric is sewn with a stitch and garments are made by stitching multiple garment pieces together. The appearance of a seam is very essential to the overall appearance of a finished garment. The quality of a seam is linked to seam puckering. That is, where undesirable gathers appear at the stitching line. There are a number of factors which may cause undesired seam appearance.

***a. structural jamming of fabric*:** in an attempt to put fabric plies together, when the sewing threads are inserted in the tightly woven fabric, puckering happens due to yarn displacement.

b. excessive thread tension: when the thread tension is too tight, a seam may experience puckering during stitching.

c. uneven ply feeding: Seams are mostly made with two or more plies. During sewing, if the plies of fabric are not evenly fed machine puckering occurs.

***d. material shrinkage**:* Garments are made of different types of fabrics which have different rates of shrinkage. Depending on the type of fabric used for a particular garment, the fabric may experience some amount of shrinkage. If the shrinkage of sewing thread is high, puckering can also happen (Sarkar, 2011).

Tensile testing

One of the most fundamental types of mechanical tests performed on a fabric is the tensile test, also known as tension test. Tensile tests are relatively inexpensive, fully standardized and simple. A fabrics reaction to force applied in tension is easily determined by pulling on the fabric. As the fabric is pulled, its strength as well as how much it will elongate is determined (Gharagozlou, n. d.). The level of elongation of a fabric is expressed as an absolute measurement in the change in length also known as “strain”. Strain is expressed either as "engineering strain" or "true strain. Possibly the easiest and most common expression of strain used is the Engineering strain. It is the ratio of the change in length to the original length. The true strain on the other hand is based on the instantaneous length of the specimen as the test progresses, where L_i is the instantaneous length and L_0 the initial length.

(a) $e = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$ (b) $\varepsilon = \ln(\frac{L_i}{L_0})$

the strip test

With this type of test, the full width of the test specimen is gripped in the tensile grip jaws of a universal testing machine. Tensile force is then applied on the fabric specimen until it ruptures. Mechanical properties to analyse include the force at rupture and the percentage elongation at maximum force and/or at rupture (Yalcin, 2018).

ultimate tensile strength

The ultimate tensile strength (UTS) is the maximum load a given specimen is able to withstand during a test. The UTS is one of the fabric properties that can be determined with a test. Depending on the type of material being tested (brittle, ductile or a substance that even exhibits both properties), the UTS may or may not be equal to strength at break. A fabric which is tested in a lab may be ductile but, after exposure to extreme cold temperatures, may transition to a brittle behaviour.

Chapter Summary

This chapter reviewed related literature on the factors and properties that aid in the achievement of quality in seams. The chapter began by identifying the theoretical framework and conceptual base of the study. It then went further to discuss the types of linings and seams, seam performance characteristics, seam quality and testing of tensile strength. These topics were reviewed in order to help in understanding the research and help in discussing the results from the findings.

CHAPTER THREE

RESEARCH METHODS

Introduction

The aim of this study was to investigate the influence of laundering and stitch density, on fabric and seam strength, elongation and efficiency of plain seams, in two types of polyester poplin linings sold on the Ghanaian market. The methodology focuses on the methods that were employed to achieve the aims and objectives enumerated in the introductory part of the study. It begins with the research design, materials and instruments used, specimen and sampling procedures, data collection procedure and data analysis.

Research Design

The research design that was used for the study is the experimental quantitative design. It is a type of research design which uses manipulation and controlled testing to understand causal processes. The experimental quantitative research is a type of study that makes use of both experimental approaches and statistical analyses of quantitative data. This design was used because the researchers' aim was to determine the seam performance of two types of polyester poplin fabrics in terms of their seam strength, elongation and efficiency after manipulating washing cycles and stitch densities. This involved the comparison of experimental and control groups, and formal, systematic measurement of quantities with the aim of determining the relationship between the variables.

The experimental type of research was used so that variables involved will be thoroughly examined. A 2×2×3 factorial design was employed for the study involving, two types of polyester poplin linings, two ranges of stitch density and three cycles of washing. In a factorial design, experimental conditions are formed by systematically varying the levels of two or more independent variables or factors (Collins, Dziak & Li, 2009). As Ary, Jacobs and Razaviah (2002) simply put it, a factorial design is an experimental design which investigates two or more independent variables at the same time, in order to study their effects singly and/or interaction with each other. The three independent variables in this study are stitch density, polyester poplin type and laundering. They were manipulated by combining them to assess their effects individually and in combination on the three dependent variables, seam strength, efficiency, and elongation.

The strip test method, a common tensile test method used to determine the breaking force and elongation of textile fabrics, was used in this study as indicated by ISO 13934-1(1999), which describes the method applicable to woven textile fabrics and specifies the determination of the maximum force of test specimens in equilibrium with the standard atmosphere for testing and of test specimens.

Data Collection Instruments

Three yards each of two types of polyester poplin fabric (Kell Star and Kell Special) and one spool of "OK" sewing thread were purchased from the market. The polyester poplin fabrics were both white in colour. This colour was chosen because dyeing of fabrics may affect the fabric, especially its strength. In order not to have a fabric already weakened by dye, the white colour was therefore chosen. The lining fabrics were chosen after a preliminary market survey done in the capital of the central region of Ghana, Cape Coast revealed that Kell Star polyester poplin lining was the most common on the market at the time. OK sewing thread was chosen because a study by Gavor and Danquah (2015) indicated that the OK sewing thread will perform better in the life of Ghanaian wax print garments with 12 SPI. Since polyester poplin fabric is often used by Ghanaian dressmakers to line the wax print, it was appropriate to use for the experiment. Hitherto, the hand sewing machine has been very popular among Ghanaian dressmakers, but with the advancement of technology, many dressmakers are turning to the electric sewing machine. In view of this, a table top electric sewing machine with a needle size of 14 was used to stitch each specimen. Olsen (2013) indicates that the standard laboratory seam type is the 301 lockstitch seam. All the specimens were therefore stitched with this stitch type. Keysoap, one of the oldest and commonest washing soap used in most households to wash wax prints as well as a standard soap in laboratory tests was purchased from the market and used for washing the specimens.

A tensile testing machine, magnifying glass and a weighing balance were also employed to test the tensile strength, yarn count and weight respectively of specimens of the two types of polyester poplin fabric purchased. A washing machine (Gyrowash®) was also used for washing the specimens.

Conditioning of fabric

As specified by ISO standard ISO 13934-1:1999 (E) (1999), before testing a fabric must be conditioned. The uncut fabric was therefore placed in an air conditioned room for 24 hours with a room temperature of 20 (+/- 2) degrees Celsius.

Labelling of Specimen

The labelling of the specimens was done based on the direction of the specimen (warp, weft), the SPI and the number of washes. Kell Star and Kell Special polyester poplin lining fabrics were labelled A and B respectively for each type. Specimens that were stitched with 12 SPI were be labelled 12 and those stitched with 15 SPI were labelled 15. SPIs of 12 and 15 were chosen because of a study by Chowdhary and Poynor (2006), which indicated that stitch densities of 15 - 18 SPI can be used for lightweight and woven fabrics, 12-14 SPI for medium weight fabrics. Stamper, Sharp, and Donnel, (1988) also asserted that fabrics which are thin and light-weight with a high yarn count should use 15 SPI. Since polyester poplin is typically used as lining it can be said to be a type of lightweight fabric, because heavyweight fabrics are not used as lining.

All warp specimens were labelled ‘P’ and all weft specimens were labelled ‘T’. Washed specimens were labelled 0, 1, 2, 3 respectively based on the number of times they were washed.

Table 1 – *Labelling of specimens*

NAME	LABEL
Warp direction	P
Weft direction	T
Kell Star lining	A
Kell Special lining	B
12 SPI	12
15 SPI	15
First washing cycle	1
Second washing cycle	2
Third washing cycle	3
No washing	0

Pretesting

Simon (1978) as cited in Cohen, Manion and Morrisson (2005) points out that before embarking upon the actual experiment, the researcher must conduct a pre-test of the experimental procedures to identify possible snags in connection with any aspect of the investigation. A pre-test was therefore carried out to identify such possible snags as well as determine the width of seam allowance at which the seam would break instead of slipping, since the ISO standard 13935-1:1999 (E) (1999) indicates that the researcher undertaking the study would have to determine the seam allowance to use.

The pretesting was done using the same instruments as employed in the main study for testing seam strength and elongation. It is prerequisite in testing seam strength and elongation, for five specimens to be used where the mean of the five specimens is determined to arrive at the strength and elongation of the particular seam.

The pretesting was done by cutting a 20 pieces of fabric measuring 35mm by 120mm from each of the two types of polyester poplin. That is, five in the warp direction and five in the weft direction for each type of polyester poplin fabric, and for each stitch density. The edges were then frayed 5mm on each side, in order to attain a measurement of 25mm by 120mm (refer to appendix A). Each specimen was then folded in half lengthwise and cut into two. With each cut specimen still together, it was sewn using a stitch density of 12 and 15 SPI, all with a seam allowance of 20mm without backstitching.

After preparing the specimen, it was then mounted in the tensile testing machine and stretched at a constant rate of 25mm/min. At this rate and with the given seam allowance, the specimen stretched till it raptured without the yarns slipping out of the seam. Therefore the seam allowance chosen and used for the entire specimen was 20mm.

Sampling Procedure

A total number of 135 specimens each were cut out of the 3 yards each of polyester poplin lining fabric purchased, making sure to cut 5cm away from the selvedge (since selvedge threads are generally strong). In order to obtain a true representation of the various sections of the fabric, specimens were cut from different sections on the fabric as illustrated in Fig 2. From the 135 specimens, 55 were not stitched to be used in testing the fabrics tensile strength, weight, yarn count, weave and yarn linear density. The remaining 80 specimens were used to test seam strength and elongation. Fifty Strands of the "OK" sewing thread were cut from the "OK" sewing thread for testing linear density.

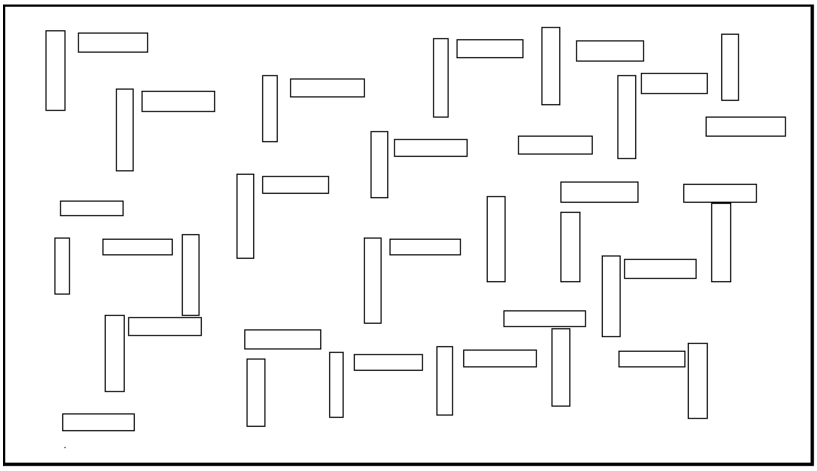

Figure 2 – Sketch of Random Sampling of Warp and Weft Specimens

Preparation of specimens for:

a. **Tensile test of fabric**

After cutting out the specimens, (measuring 35mm by 120mm) that is, in the warp and weft directions, they were frayed 5mm on each side in the lengthwise direction as shown in Appendix A. This was done in order to ensure that every thread running through the specimen is full to ascertain a more true result when tested.

For the testing of tensile strength and elongation of the unstitched, washed and unwashed fabric, a total of 40 specimens each for the two types of polyester poplin were cut for the experiment. The 40 specimen was made up of 20 specimens in the warp direction and 20 in the weft direction. With each group of 20 specimens, 5 each were unwashed, washed once, twice and three times.

Table 2 – *Number of specimens for washing cycles*

№ of Specimen	**Procedure**
5 warp, 5 weft	Unwashed
5 warp, 5 weft	Washed once
5 warp, 5 weft	Washed twice
5 warp, 5 weft	Washed thrice
Total of 40 specimens	

b. Tensile test of seam

All the specimens were stitched using an SPI of 12 and 15. The 80 specimens each of the two types of lining fabrics to be stitched were cut 160mm by 35mm, folded across the width, cut into two at the centre and stitched leaving a seam allowance of 20mm. The ISO 13935-1:1999(E) (1999) indicates that a seam can be sewn parallel to the warp or weft direction or both for testing. The specimens were therefore stitched parallel to both the warp and the weft directions. The “OK” sewing thread was used in both the upper and the bobbin thread to stitch all specimens; 40 specimens for 12 SPI and 40 specimens for 15 SPI, for each lining type, as illustrated in Table 2. The 20mm seam allowance used was chosen because ISO specifies that the group or individual undertaking the experiment must decide on the seam allowance to use which will result in the fabric breaking instead of slipping during a tensile test. The pre-test which was carried out showed that with the 20mm seam allowance complete seam slippage will not occur.

Data Collection Procedure

The washing, weighing and fibre testing of specimens were carried out at the Ghana Standards Authority with the aid of qualified technicians. And the tensile tests were conducted at the School of Engineering Sciences, Material Science Department in the University of Ghana, from the 14th of February, 2017 to the 28th of February 2017. Introductory letters was taken from the department of VOTEC and sent to these institutions who graciously granted the use of their premises. Copies of the introductory letters and receipts are shown in Appendices K, L, M, N and O.

The measurement of the specimens was 120 × 25mm although the standard measurement for testing woven fabric as indicated by Olsen (2013) is 400 × 100mm. This was due to the specifications of the tensile test machine available.

Preparation of soap solution

The stock solution was prepared by placing a 72g bar of block soap in 14.4 litres of water and heating on fire till all the soap dissolved. For one litre of water, 5g of soap is needed with 2g of sodium carbonate which acts as an auxiliary to control the foaming of the solution.

Washing of specimens

The Gyrowash® washing machine, which contains 8 cylinders, was used to wash the specimen. Five specimens were placed in each cylinder (giving a total of 40 specimens in one round) and washed for 30 minutes at a temperature of 60°C. Since the specimens were 240, six rounds of washing were done with each cylinder taking 300ml of soap solution. Two steel balls were placed in each cylinder for agitation. Specimens were taken out and rinsed after 30 minutes of washing and dried in the open under the sunlight. All specimens were taken out of the sunlight right after drying. The washing and drying of the specimens was done under the supervision of a lab technician at the Ghana Standards Authority in accordance with the standards used for washing fabric samples for testing.

Testing for tensile strength, elongation and efficiency of fabric and seams

A Universal Tensile Tester (MARK-10) was used in conducting the tensile strength tests for all the specimens. The gauge length of the tensile testing machine was set at 120mm ± 1mm with a rate of extension set at 25mm/min. The maximum force at rupture was recorded in Newton (N). The area of the specimens was 3000mm^2; calculated by multiplying the length by the breadth of the specimen, that is, 120mm × 25mm. The rate of extension and area were used to calculate the tensile strength. The force at break and the extension at break of seams and fabric were recorded for each specimen in both the warp and the weft directions after each cycle of washing. The unwashed specimens served as controls. Strain, percent elongation, ultimate tensile strength and seam efficiency were calculated using the following formulae:

(a) $Strain = \frac{Change\ in\ length\ (\Delta l)}{Initial\ length\ (\mathrm{lo})} = \frac{\text{Final length (lf)– Initial length (lo)}}{\text{Initial length (lo)}}$

(b) $\%\ elongation = Strain\ \times 100$

(c) $Ultimate\ tensile\ strength\ of\ specimen = \frac{Load\ (N)}{Area}$

(d) $Seam\ efficiency = \frac{Seam\ strength}{Fabric\ strength}\ \times 100$

Yarn linear density of fabrics and thread

Joseph (1986) stated that in describing a woven textile fabric, its average width, length, number of yarns per inch in warp and filling, yarn size and weight in grams should be cited. In testing for the yarn linear density of the lining fabrics, threads were removed from seven rectangular strips of fabric, measuring 500mm by 25mm cut randomly from the lining fabric, in order to obtain a true representation of the fabric, as illustrated in Fig 3. Two rectangular strips were cut out in the warp direction and five strips for the weft direction. One hundred strands were pulled out from the warp strips and 250 strands were pulled out from the weft rectangular strips, giving a total of 350 strands of threads from the two types of lining fabric as specified by the International Standard, 1SO 7211/5 (1984) (determination of linear density of yarn removed from fabric). Fifty strands of the “OK” thread were also cut 500mm long and used to test for the yarn linear density of the thread.

An “OHAUS® Adventurer™ Pro” balance was used to weigh the strands of thread which had been removed. The 100 strands of thread removed from the warp rectangular strip were weighed directly but the 250 strands removed from the weft rectangular strips for each lining type were divided into five groups of fifty, weighed individually and recorded. The mean of the five groups was then used to calculate the linear density of the fabrics and thread, using the formula indicated in 1SO 7211/5 (1984) given as:

$$Linear\ density\ in\ tex\ units$$
$$= \frac{Mass(g) of\ thread\ from\ fabric\ \times constant\ (1000)}{Length\ (m) of\ thread}$$

Average weight, yarn count and weave of fabrics

Five specimens each of the two types of polyester poplin, were cut 100mm by 100mm giving an area of $0.01m^2$ and weighed individually using the " OHAUS Adventure™ Pro" weighing balance. The mean of the five specimens from each fabric type was then calculated and then divided by the area to determine the average fabric weight. Two specimens each for the two types of fabric, (one for warp and one for weft) were also cut one inch by one inch and the threads were picked out one after the other using a pin and counted. This was used to ascertain the yarn count. One specimen each was used to determine the fabric weave using a magnifying glass.

Testing Fibre Type

The solubility test which involves the use of chemicals was used in testing the fibre content of the fabrics. A 100% concentrated solution of Meta-Cresol chemical was used at a temperature of 139°C. The two lining fabric were cut into pieces and placed in different beakers. The solution was put in the beakers after which the fabrics were placed in the solution. After 5 minutes of shaking the beakers the fabrics dissolved which indicated that the fabrics were 100% polyester.

Data Analysis

After the experiment was conducted at the lab, readings were recorded for each of the test specimen. Microsoft Excel and the IBM Statistical Package and Service Solution (SPSS) for Windows version 21 were used. Analysis of the fabric's yarn linear density, yarn count, weight, strength and elongation were done using means and standard deviations. The means and standard deviations were also used to describe the deformation of the warp seams used in measuring the differences, that is, TYPE 1, 2, 3 and 4 deformations

To answer the research questions, means and standard deviations were employed to describe the fabric performance characteristics, that is, the yarn liner density, yarn count and weight; as well as determine if any difference exists between the strength of the polyester lining fabrics and the strength of plain seam in the same fabric after three washing cycles.

In testing hypotheses 1, 2, 4, 5, 7 and 8, Independent sample t-test was used where fabric type and stitch density were taken against the dependent variables seam strength, seam elongation and seam efficiency. The rationale for using the independent t-test was based on the fact that, the researcher was interested in ascertaining the differences that will exist between two independent variables which are measured on a continuous scale

For hypotheses 3, 6 and 9, One-Way ANOVA was employed where the independent variable - washing cycles was taken against the dependent variables (seam strength, seam elongation and seam efficiency). The one-way ANOVA was used to know whether significant differences will exist in three different categorical variables against the dependent variable, all of which are measured on a continuous scale.

Chapter Summary

The chapter discussed the research design, description of the materials and instruments used, how the fabrics were conditioned, labelling of specimens, the pre-test, sampling procedure, how the fabrics were prepared for the various tests, the procedures used in testing the linear density, yarn count, weight and tensile strength of the fabric. The chapter finally discussed the methods which were used for the analysis of the data collected.

In the collection of data some limitations were encountered. These limitations relate to the environment during testing. Specimens were not dried on the same day and as a result internal validity might be compromised since there could have been a variation of the intensity of sunlight used in drying test specimens.

Again, only one type of thread and two types of polyester poplin lining fabric out of the several types on the market were employed for the study. These can therefore limit the prospect of generalizing the research findings to all polyester poplin lining fabrics.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter covers the analysis, presentation and interpretation of the findings resulting from this study. The purpose of the study was to investigate the influence of laundering and stitch density, on fabric and seam strength, elongation and efficiency of plain seams, in two types of polyester poplin lining fabrics sold on the Ghanaian market. The analysis and interpretation of data were carried out based on the results of the research questions and hypotheses set for the study. The analysis was based on the 100% return data obtained from the laboratory experiment. Readings recorded for each of the tests identified from stitched, unstitched, washed and unwashed specimens are analysed and discussed in this chapter. Microsoft Excel was used for the computations of the raw data from the laboratory and the Statistical Package and Service Solution (SPSS) for Windows version 21 was employed in analysing the data for the study.

The data was analysed using descriptive statistics (means and standard deviations) as well as inferential statistics (independent t- test, one way ANOVA) at 0.05 alpha levels. The research findings were presented based on the research questions and hypothesis formulated for the study.

This chapter is presented with the headings below:

1. Fabric performance characteristics
2. Analysis of rupture in test specimens after tensile strength test
3. Difference between tensile properties of fabric (strength and elongation) and tensile properties of seam (strength and elongation).

4. Differences between fabric types, stitch densities and washing cycles with regard to seam performance properties (strength, efficiency and elongation).

Results

Research Question 1: What are the fabric performance qualities (yarn count, weight, and linear density) of the two types of polyester poplin lining fabrics?

Performance characteristics of fabrics

To answer research question one, selected structural and performance characteristics of the fabrics and the sewing thread were determined. The fabrics were both made from polyester poplin and woven in a plain weave of 1x1 repeat in both directions. The sewing thread used for the investigations was OK polyester sewing thread. To achieve this, means and standard deviations were computed for each of the variables. The results are presented in Table 3.

Table 3 presents the results of the performance of qualities of the two types of polyester poplin linings. From Table 3, the results show that, the warp threads of Kell Star had more yarn count (M = 80, SD = 2.16) than the weft direction (M = 42.25, SD = 1.5). Kell Special fabric also had more yarn count in the warp direction (M = 90.75, SD = 2.5) than in the weft direction (M = 59, SD = 1.41). A lightweight fabric is typically between 30-150 GSM, (http://blog.fabricuk.com/understanding-fabric-weight/). The two types of fabric can therefore be classified under lightweight fabrics which are suitable for use as lining.

Table 3 – *Fabric Performance Characteristics of Fabric*

Characteristic	N	Mean	Std. Dev.
Yarn count			
Kell Star warp	5	80 E.P.I	2.16
Kell Star weft	5	42.25 P.P.I	1.5
Kell Special warp	5	90.75 E.P.I	2.5
Kell Special weft	5	59 P.P.I	1.41
Weight (g/m^2)			
Kell Star	5	69.70	1.25
Kell Special	5	90.22	1.68
Yarn linear density (Tex)			
Kell Star warp	1	14	
Kell Star weft	5	7	0.14
Kell Special warp	1	14	
Kell Special weft	5	8	0.40
OK sewing thread	5	15	
Tensile strength (N/mm^2)			
Kell Star warp	5	0.048 (143N)	4.24
Kell Star weft	5	0.023 (69N)	3.33
Kell Special warp	5	0.061 (182N)	5.62
Kell Special weft	5	0.042 (125N)	7.42
Elongation (%)			
Kell Star warp	5	10.76	1.30
Kell Star weft	5	15.63	2.46
Kell Special warp	5	12.85	0.95
Kell Special weft	5	19.10	1.23

Source: Field Data, Quarcoo (2017); P.P.I: picks per inch, E.P.I: ends per inch

Table 3 further shows that, Kell Special weighed more (M = 90.22, SD = 1.68) than Kell Star (M = 69.70, SD = 1.25). However, the standard requirement according to GS 1032: 2013 should be a minimum of 140g/m^2. The findings therefore show that the two lining types are below the required standard. With regard to the yarn linear density, both Kell Star and Kell

Special lining fabrics had equal Tex in the warp direction (M = 14). However, in the weft direction Kell Special recorded a higher Tex (M = 8, SD = 0.40) than Kell Star (M = 7, SD = 0.14).

Table 3 again reveals that the warp threads for both Kell Star and Kell Special had greater strength (M = 0.048, load =143N); (M = 0.061, load = 182N) respectively than the weft threads (M = 0.023, load = 69N); (M = 0.042, load =125N) respectively. According to GS 1032: 2013 the minimum load for the breaking strength should be 250N for warp and 200N for weft. The warp for Kell Star and Kell Special recorded a load of 143N and 182N respectively, both of which are less than the required standard. In the weft Kell star and Kell Special recorded a load of 69N and 125N respectively. In the weft direction also the minimum requirement was not attained. This means the minimum requirement for a woven lining fabric according to GS 1032: 2013 was not met.

Since the warp threads for both Kell Star and Kell Special had greater strength than the weft threads, the warp threads for both types of fabric showed less elongation (M = 10.76, SD = 1.30); (M = 12.85, SD = 0.95) as compared to the weft threads (M = 15.63, SD = 2.46); (M = 19.10, SD = 1.23) respectively.

Analysis of rupture in test specimens

During the data collection, it was noted that the tests specimens ruptured differently. Four forms of rupture were identified during the collection of data. These are: rupture of the seam (TYPE 1), damage of fabric with seam intact (TYPE 2), yarn slippage with seam still intact (TYPE 3) and yarn slippage before seam rupture (TYPE 4). These are shown in Appendices

B, C, D and E respectively. The observed differences are similar to the differences that occurred in a study by Gribaa, Amar & Dogui, (2006) on the influence of sewing parameters on the tensile behaviour of textile assembly. In their study they noted three types of deformation, namely (a) breaking of sewing thread, (b) breakage of sewing thread after seam slippage and (c) damage of fabric. Another study by Danquah (2010), reported two types of deformation, that is, (a) rupture of stitching lines (sewing thread) and (b) damage of the fabric.

Table 4 shows that out of the 160 stitched specimens, 52 experienced seam rupture, 68 - fabric rupture with seam intact, 15 - yarn slippage before seam rupture and 25 - yarn slippage with seam still intact. With regard to the warp specimens of Kell Star lining fabric, the specimens with an SPI of 12 experienced seam rupture and all the cycles of washing resulted in the breakage of stitches. The unwashed warp specimen however had only 2 specimens experiencing seam rupture with the rest of the 3 experiencing fabric rupture with seam intact. Indicating that with the unwashed fabric, the seam was stronger than the fabric thus, causing the fabric instead of the seam to rupture. Kell Star warp specimens with stitch density of 15 on the other hand experienced fabric rupture with the seams still intact. This is attributed to the strength of the seam being greater than the fabric.

Table 4 – *Rupture of Seams*

Seam rupture	Fabric rupture with seam intact	Yarn slippage before seam rupture	Yarn slippage with seam intact
Kell Star			
(2) A.P.0.12	(3) A.P.0.12	(2) A.T.0.12	(3) A.T.0.12
(5) A.P.1.12	(5) A.P.0.15	(5) A.T.1.12	(2) A.T.2.12
(5) A.P.2.12	(5) A.P.1.15	(3) A.T.2.12	(5) A.T.0.15
(5) A.P.3.12	(5) A.P.2.15	(5) A.T.3.12	(5) A.T.1.15
	(5) A.P.3.15		(5) A.T.2.15
			(5) A.T.3.15
Kell Special			
(5) B.P.0.12	(2) B.T.0.12		
(5) B.P.1.12	(5) B.T.1.12		
(5) B.P.2.12	(5) B.T.2.12		
(5) B.P.3.12	(2) B.T.3.12		
(3) B.T.0.12	(5) B.T.0.15		
(3) B.T.3.12	(5) B.T.1.15		
(5) B.P.0.15	(5) B.T.2.15		
(2) B.P.1.15	(5) B.T.3.15		
(2) B.P.2.15	(3) B.P.1.15		
	(3) B.P.2.15		
	(5) B.P.3.15		
52 specimens	**68 specimens**	**15 specimens**	**25 specimens**

Again from Table 4, it is evident that all the weft specimens underwent some degree of yarn slippage- either before seam rupture or with the seam intact. For specimens stitched with 12 SPI, after the first and third washing cycles all test specimens underwent some amount of yarn slippage before the seam broke. The unwashed specimen had two of the test specimens with seam rupturing after yarn slippage with the remaining three having seams intact though the yarns had slipped and the seam was intact. The specimens which had been washed twice also had three test specimens experiencing seam rupture after the slippage of yarn with two seams staying intact with yarn slippage. All the weft specimens of Kell Star lining with an SPI of 15 experienced yarn slippage with seam intact.

All warp specimens from Kell Special lining fabric, with an SPI of 12 underwent seam rupture. With the weft specimens (with 12 SPI) however, only three each of the unwashed sample and the sample washed three times experienced seam rupture. The remaining two (unwashed and washed thrice) each underwent fabric rupture with the seam intact. The first and second washing of the weft specimens on the other hand resulted in specimens suffering fabric rupture with seam intact. With the warp specimens with 15 SPI, all the unstitched samples suffered seam rupture. The specimens washed once and twice had two of the samples suffering seam rupture with the remaining three each and the all specimens washed thrice encountering fabric rupture with seam intact. A close look at the analysis tells that, the strength of the warp specimens of Kell Special lining fabric declined with washing with the third wash resulting in a fabric which was too weak to withstand the pulling forces therefore rupturing while the seam was still strong. After each washing cycle, all weft specimens with SPI of 15 underwent rupturing with seam intact.

Research Question 2: What is the seam strength of polyester poplin lining when stitched with "OK" sewing thread at 12 and 15 SPI?

This section presents the results on the seam strength of polyester poplin lining when stitched with "OK" sewing thread at 12 and 15 SPI in means and standard deviation as shown in Table 5.

Table 5 presents results showing the unwashed fabric strength and seam strength after stitching with stitch density 12 for the two types of polyester poplin lining fabrics. Specimens with stitch density of 15 could not be recorded because the seams were too tight thereby causing the fabric to rapture while the seam was still intact for Kell Special lining fabric, and yarn slippage with intact seams for Kell Star lining fabric.

Table 5 – *Seam Strength of Polyester Poplin Lining Fabrics when Stitched With 12 and 15 SPI*

Fabric type/direction	Unstitched		SPI12	
	M(kPa)	SD	M(kPa)	SD
Kell Star				
Warp	47.50	4.24	42.92*	0.12*
Weft	23.00	3.33	11.58*	0.12*
Kell Special				
Warp	60.53	5.62	46.13	4.81
Weft	41.67	7.42	42.61*	7.70*

Source: Field Data, Quarcoo (2017) *less than 5 specimens

It is evident from Table 5 that, in the warp direction of Kell Star polyester poplin lining fabric, the strength of the fabric was more (M = 47.50, SD = 4.24) than it was when stitched with 12 SPI (M = 42.92*, SD = 0.12*).

In the weft direction too, the fabric recorded higher seam strength (M = 23.00, SD = 3.33) than that of 12 SPI (M = 11.58*, SD = 0.12*). It was also observed that, the unstitched Kell Special polyester poplin lining fabric in the warp direction was of greater strength (M = 60.53, SD = 5.62), than the specimen stitched with 12 SPI (M = 46.13, SD = 4.81). In the weft direction however, the stitched fabric was stronger (M = 42.61*, SD = 7.70*) than the unstitched fabric (M = 41.67, SD = 7.42). Figure 3 is a graphical presentation of the results in Table 5 which indicates the seam strength of unwashed samples.

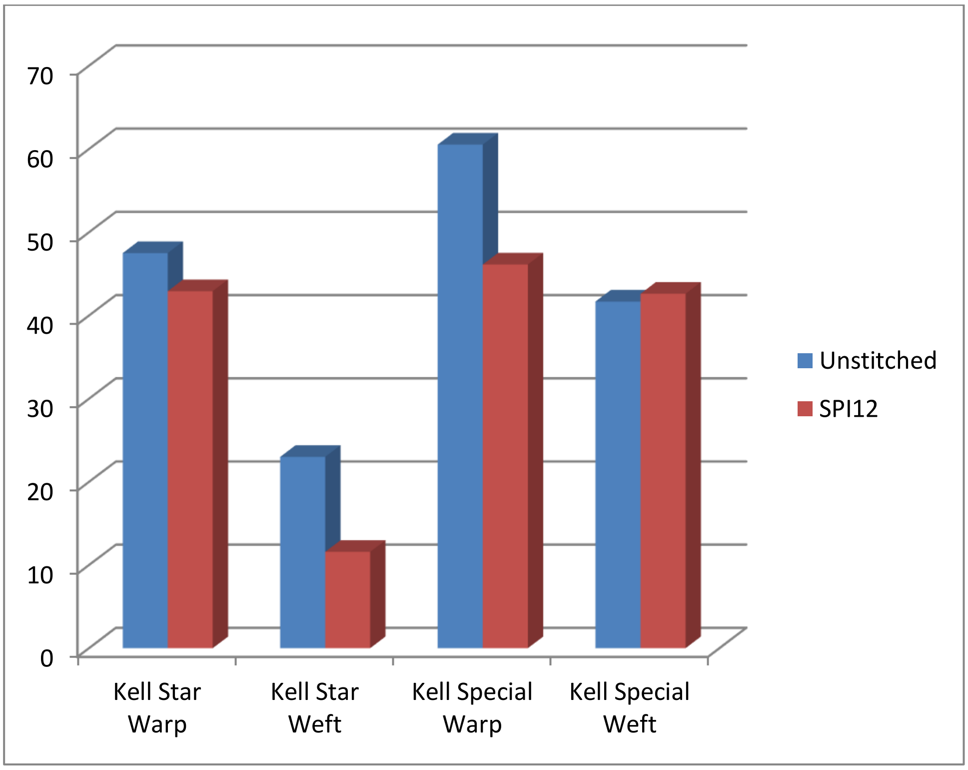

Figure 3 –chart showing seam strength of unwashed samples

Difference between tensile properties of fabric (strength and elongation) and tensile properties of seam (strength and elongation)

To find out if differences existed in the strength and elongation of the seams and fabric after three washing cycles, which answered research question 3 and 4, means and standard deviations were employed. The results are presented in Table 6 and 7 for strength and 8 and 9 for elongation.

Research Question 3: **What is the difference between fabric strength and seam strength after three washing cycles for the two types of polyester poplin lining fabrics?**

This section presents the results on the difference between fabric strength and seam strength after three washing cycles for the two types of polyester poplin lining fabrics in means and standard deviation as shown in Table 6.

Table 6 – *Comparisons between Fabric Strength (Warp) and Seam Strength (Weft Seams) after Washing*

Fabric /seam	Unwashed		1st wash		2nd wash		3rd wash	
	M	SD	M	SD	M	SD	M	SD
Kell Star								
Unstitched	47.50	4.24	44.00	6.71	48.43	3.78	41.87	7.28
12 SPI	42.92*	0.12*	34.5	7.5	27.8	2.3	22.7	3.44
Kell Special								
Unstitched	60.53	5.62	58.00	6.02	55.57	1.26	56.03	3.46
12 SPI	46.1	4.8	48.5	9.7	48.9	2.7	45.6	13.1
15 SPI	-	-	54.9*	1.1*	54.0*	0.71*	-	-

Source: Field Data, Quarcoo (2017) *less than 5 specimens

It is noted that the strength of the unstitched specimens indicate the fabric strength. From Table 6, it is evident that for the unstitched specimens of Kell Star lining fabric, the second washing cycle had a greater strength (M=48.43, SD=3.78) than the unwashed specimen (M=47.50, SD=4.24) and after the third washing cycle the strength declined (M=41.87, SD=7.28). For all the cycles of washing, the fabric (that is, the unstitched specimens) had a greater strength than the stitched specimens with 12 SPI. Specimens with 15 SPI could not be recorded since the seams did not rupture.

For Kell Special lining fabric, the strength of the fabric was greater than the seam strength for both 12 and 15 SPI in all the cycles of washing. The seam strength of specimens with 15 SPI however, was greater than that of specimens with 12 SPI in all the cycles of washing.

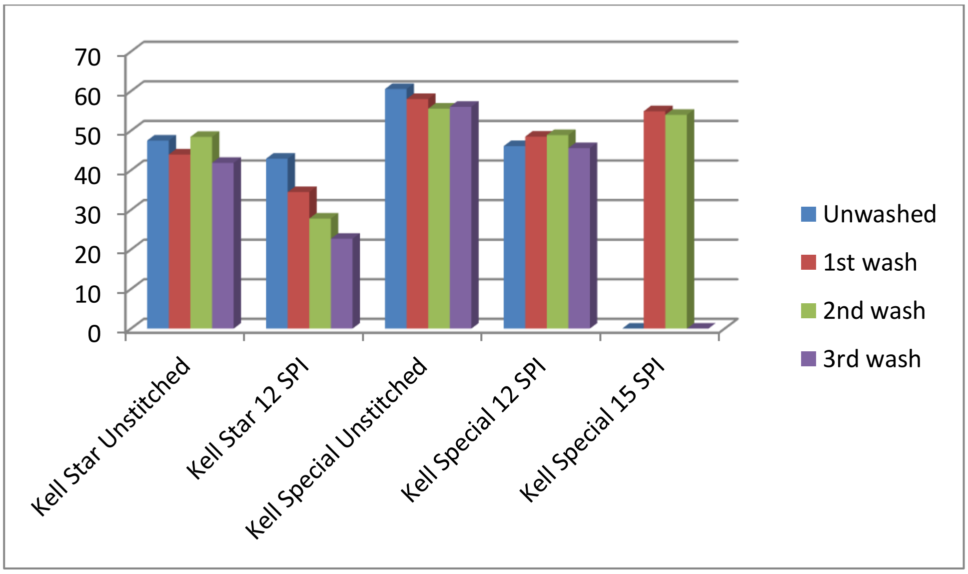

Figure 4: Chart showing comparisons between fabric strength (warp) and seam strength (weft seams) after washing

Table 7 – *Comparisons between Fabric (Weft) and Seam Strength (Warp Seams) after Washing*

Fabrics /seams	Unwashed		1st wash		2nd wash		3rd wash	
	M	SD	M	SD	M	SD	M	SD
Kell Star								
Unstitched	23.00	3.33	20.07	2.65	17.73	1.61	18.23	2.18
12 SPI	11.58*	0.12*	10.47	0.87	8.72*	0.54*	12.17	2.16
Kell Special								
Unstitched	41.67	7.42	35.97	2.80	41.97	12.95	37.73	2.51
12 SPI	42.61*	7.70*	-	-	-	-	39.17*	2.33*

Source: Field Data, Quarcoo (2017) * Less than 5 specimens

From Table 7, it was noted that for Kell Star lining fabric, the unstitched specimens (representing the fabric) in all the cycles of washing had more strength than the stitched specimens with 12 SPI. Similar to the weft seams, the warp seams with an SPI of 15 could also not be recorded due to tight stitches causing the seams to remain intact while the yarns slipped from the seam.

For Kell Special lining fabric, the specimen with stitch density 12 recorded higher strength than the fabric. The first and second cycle of washing could however not be recorded due to fabric damage with intact seams. The third washing of the specimen also recorded a greater strength than the fabric, although the unwashed specimens with 12 SPI had the greatest strength (M = 42.61, SD = 7.70). There was no record for 15 SPI due to fabric failure.

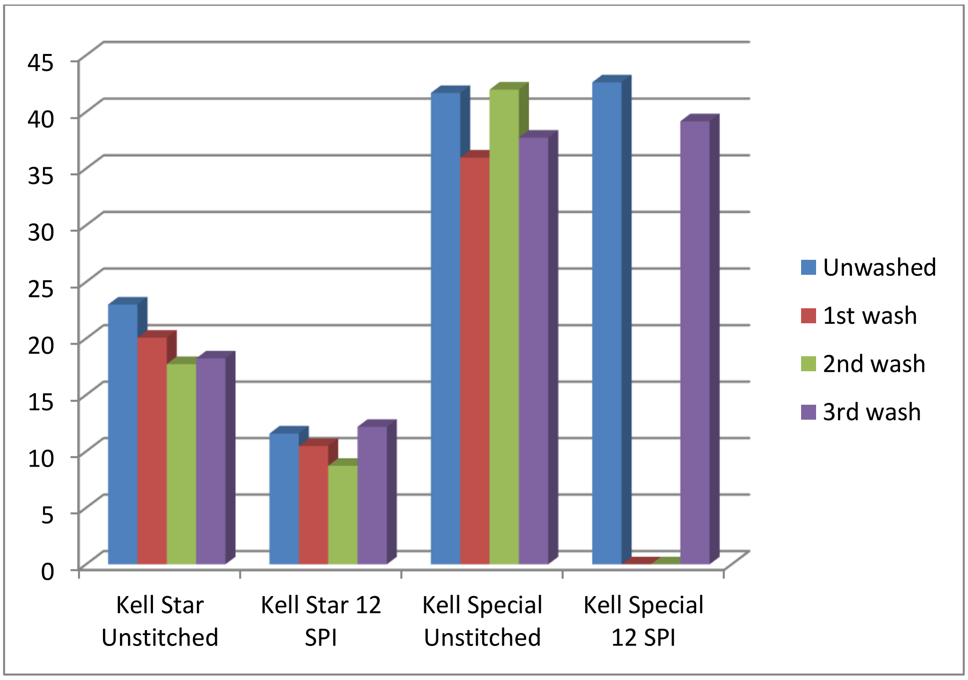

Figure 5: Chart showing comparisons between fabric (weft) and seam strength (warp seams) after washing

Research Question 4: What is the difference between fabric elongation and seam elongation after three washing cycles for the two polyester poplin lining types?

This section presents the results of the comparison between fabric and seam elongation after three washing cycles in means and standard deviation. The results are presented in Table 8 and 9.

Table 8 – *Comparisons between Fabric Elongation (Warp) and Seam Elongation (Weft Seams) after Washing*

Fabrics /seams	Unwashed		1st wash		2nd wash		3rd wash	
	M	SD	M	SD	M	SD	M	SD
Kell Star								
Unstitched	10.76	1.30	9.38	1.55	10.76	0.78	8.68	2.46
12 SPI	14.76*	1.23*	16.32	1.39	12.15	5.06	13.5	1.30
Kell Special								
Unstitched	12.85	0.95	9.72	0.95	12.15	1.23	10.76	0.78
12 SPI	14.58	2.63	13.9	1.74	14.24	1.45	13.9	2.13
15 SPI	-	-	13.89*	0.00*	13.89*	2.46*	-	-

Source: Field Data, Quarcoo (2017) * Less than 5 specimens

Table 8 shows that for Kell Star lining fabric, the seam elongation was more than the fabric elongation for all the cycles of washing. Specimens with 12 SPI had more elasticity after the first washing cycle (M = 16.32, SD = 1.39), and the least elasticity after the second washing cycle (M = 12.15, SD = 5.06). Kell Special lining fabric also showed that specimens with 12 SPI had more elongation in the unwashed state (M = 14.58, SD = 2.63) than in the subsequent washing cycles. Stitch density 15 did not “give” as much as stitch density 12. This is attributed to the fact that 15 SPI had a firmer grip on the seams thereby reducing the elasticity of the seam.

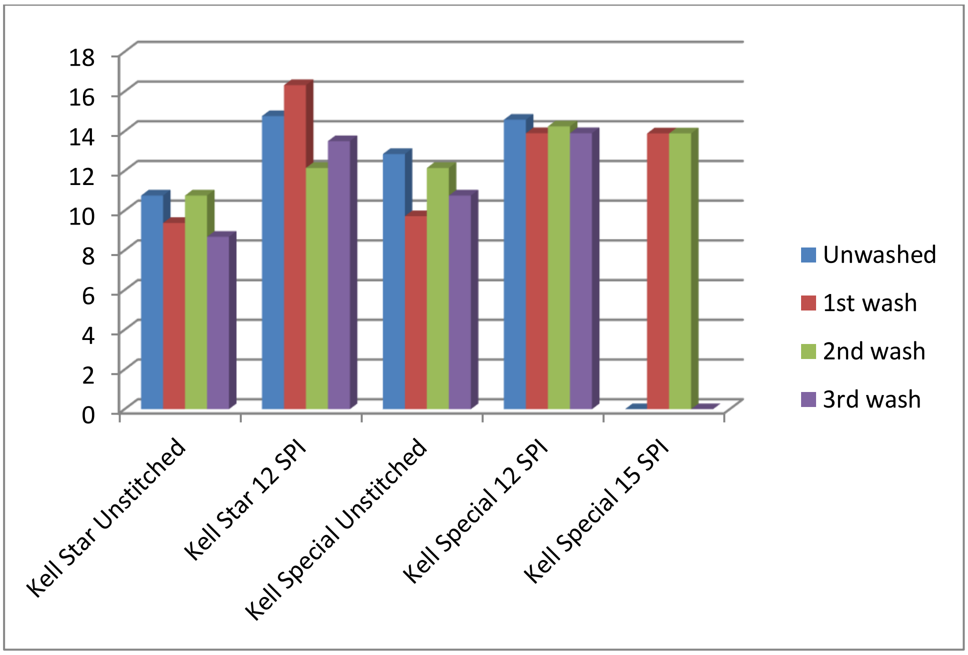

Figure 6: Chart showing comparisons between fabric elongation (warp) and seam elongation (weft seams) after washing

Table 9 – *Comparisons between Fabric Elongation (Weft) and Seam Elongation (Warp Seams) After Washing*

Fabrics /seams	Unwashed		1st wash		2nd wash		3rd wash	
	M	SD	M	SD	M	SD	M	SD
Kell Star								
Unstitched	15.63	2.46	14.93	1.98	11.46	1.98	13.54	1.45
12 SPI	21.70*	1.23*	25.35	1.39	20.83*	3.01*	27.8	2.91
Kell Special								
Unstitched	19.10	1.23	17.36	1.23	15.63	1.23	17.36	1.23
12 SPI	22.57*	0.00*	-	-	-	-	23.73*	1.00*

Source: Field Data, Quarcoo (2017) * Less than 5 specimens

Table 9 illustrates that, the unstitched and unwashed specimens of Kell Star lining fabric possessed more elasticity (M = 19.10, SD = 1.23) than the subsequent washing cycles. Warp seams with 12 SPI had more elasticity than the fabric with the third washing cycle recording the highest percentage of elongation (M = 27.8, SD = 2.91) and the second washing cycle recording the least percentage of seam elongation (M = 20.83, SD = 3.01).

Similar to Kell Star lining fabric, Kell Special lining fabric also showed that the seams possessed more give than the fabric. Specimens with 12 SPI washed once and twice could however not be recorded due to fabric failure. None the less, the specimens washed three times had more elongation (M = 23.73, SD = 1.00) as compared to the unwashed specimen (M = 22.57, SD = 0.00).

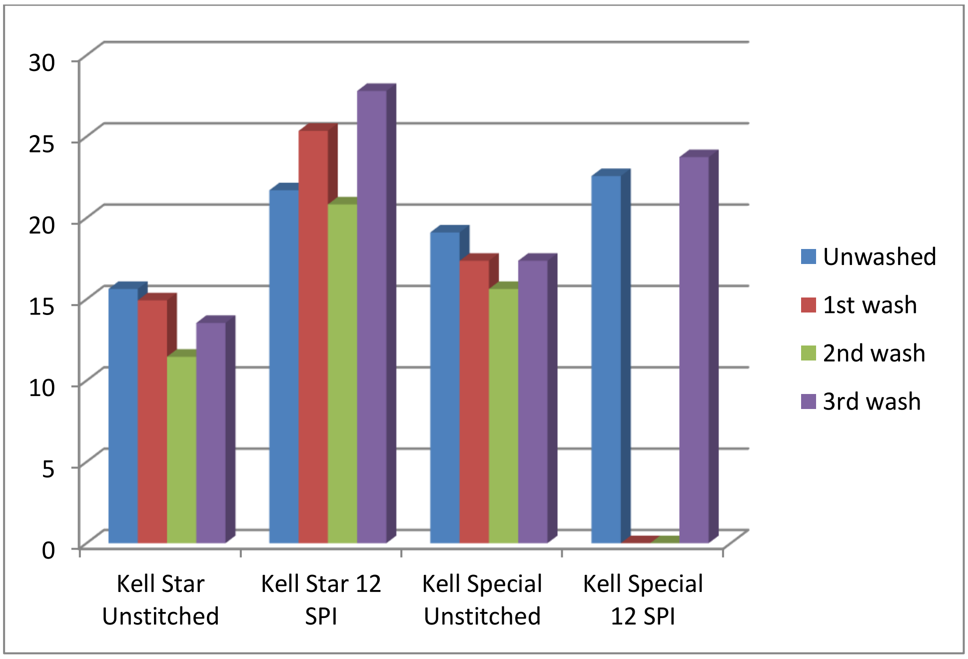

Figure 7: chart showing comparisons between fabric elongation (weft) and seam elongation (warp seams) after washing

Differences between fabric types, stitch densities and washing cycles with regard to seam performance properties (strength, efficiency and elongation)

In order to compare seam performance properties with fabric types, stitch densities and washing cycles with regard to strength, efficiency and elongation, which required testing of hypotheses inferential statistics (Independent sample t-test, one way ANOVA) was employed.

Research Hypothesis 1

$H_0$1: There is no significant difference between fabric types (Kell Star and Kell Special) with regard to seam strength of a plain seam in a polyester poplin lining fabric

This section presents the results of the effect of the fabric types on seam strength. Table 10 shows the Independent t-test analysis of fabric type and seam strength of a plain seam in a polyester poplin lining fabric.

Table 10 – *Independent t-test analysis of fabric types and seam strength of a plain seam in a polyester poplin lining fabric*

Fabric direction/type		Mean	S.D.	df	*t* - value	*p* - value
	Warp					
	Kell Star	15.98	18.02	14	-3.116	.008*
Seam strength	Kell Special	44.34	18.39			
	Weft					
	Kell Star	5.37	5.82	14	-0.693	.500
	Kell Special	10.22	18.95			

Source: Field data, Quarcoo (2017), *Significant p < 0.05

Table 10 illustrates the independent t-test analysis of fabric types and seam strength of a plain seam in a polyester poplin lining fabric. From Table 10, the results show that there is a statistically significant difference between the warp of Kell Star lining and Kell special lining (t (14) -3.116, p = .008). Therefore, the null hypothesis which stated that “there is no statistical significant difference between fabric type and seam strength” is rejected. In the weft direction however, the results show conformity to the null hypothesis which states that there is no statistically significant difference between Kell Star and Kell Special lining fabric (t (14)-0.693, p = .500). The null hypothesis was therefore retained.

Research Hypothesis 2

$H_0$2: There is no significant difference between stitch densities (12 SPI and 15) with regard to seam strength of a plain seam in a polyester poplin lining fabric.

This section presents the results of the difference between stitch densities with regards to the seam strength of a plain seam in a polyester poplin lining fabric. The results are presented in Table 11.

Table 11 – *Independent t-test analysis of stitch densities and seam strength of a plain seam in a polyester poplin lining fabric*

Fabric direction/ SPI		Mean	S.D.	Df	*t* - value	*p* - value
	Warp					
	SPI12	39.62	10.05	8.71	1.765	.112
Seam	SPI15	20.71	28.59			
strength	**Weft**					
	SPI12	15.59	16.36	7	2.695	.031*
	SPI15	0.00	0.00			

Source: Field data, Quarcoo (2017), *Significant p < 0.05

Table 11 shows the results of independent t-test analysis of stitch densities and seam strength of a plain seam in a polyester poplin lining fabric. From Table 11, there was no statistically significant difference between stitch density 12 and stitch density 15 in the warp of the fabric ($t (8.71) = 1.765$, $p = .112$). In the weft direction on the other hand, a statistically significant difference was apparent ($t (7) = 2.695$, $p = .031$.

Research Hypothesis 3

$H_0$3: There is no significant difference between washing cycles (unwashed, first cycle, second cycle and third cycle) with regard to seam strength of a plain seam in a polyester poplin lining fabric.

To compare the differences between the washing cycles (unwashed, first wash, second wash and third wash) and seam strength, in both directions (warp and weft), one way analysis of variance was deemed appropriate for the analysis. However, prior to conducting ANOVA, certain assumptions need to be met. These include test for normality and homogeneity of variance. The results are presented in Table 12 and 13.

Table 12 – *Test of Homogeneity of Variances for Washing Cycles against Seam Strength*

	Levene Statistic	df1	df2	Sig.
	Warp			
Seam strength	0.018	3	12	.997
	Weft			
	2.310	3	12	.128

Source: Field data, Quarcoo (2017), *Significant $p < 0.05$

Table 12 shows the results for the test of homogeneity of variance. Homogeneity of variance is an assumption which must be satisfied for successful analysis of variance to be conducted (Pallant, 2005). From Table 12, the sig. value for the Levene test in the warp and weft direction is .997 and .128 respectively, both of which are greater than the alpha value of $p = 0.05$ which shows that the variances were assumed equal. That is, $F(3, 12) = 0.018$, $p = .997$ for the warp and $F(3, 12) = 2.310$, $p = 0.128$ for the weft. Hence the ANOVA table was studied.

Table 13 presents the results of the ANOVA test. In both the warp and weft directions, the overall *F* ratio for the One-way ANOVA is not significant at the Sig. value of $p = 0.05$. From the test it is evident that the F-ratio (.545) for warp and (.786) for weft are not significant ($p = .661$ and $p = .524$ respectively) at the 0.05 alpha level. This implies that in both directions, there was no significant difference among the mean scores of the washing cycles with regards to their seam strength. This therefore implies that the results failed to reject the null hypotheses stated as "There is no significant difference between washing cycles and seam strength".

Table 13 – *Summary of ANOVA results for Washing Cycles against Seam Strength*

	Variables	Sum of Squares	df	Mean Square	F	Sig.
Seam Strength	**Warp**					
	Between Groups	942.99	3	314.331	.545	.661
	Within Groups	6915.44	12	576.286		
	Total	7336.5	15			
	Weft					
	Between Groups	467.31	3	155.770	.786	.524
	Within Groups	2378.26	12	198.189		
	Total	2845.57	15			

Source: Field data, Quarcoo (2017), *Significant $p < 0.05$

Research Hypothesis 4

H_{O4}: There is no significant difference between fabric types with regard to seam efficiency of a plain seam in a polyester poplin lining fabric.

This section presents the results of the difference between fabric types with regard to seam efficiency of a plain seam in a polyester poplin lining fabric. The results are presented in Table 14.

Table 14 presents the results of independent t-test analysis of fabric types with regard to seam efficiency of a plain seam in a polyester poplin lining fabric. From Table 14, there was a statistically significant difference between Kell Star and Kell Special in the warp direction (t (14) = -2.226, p = 0.04). The weft direction on the other hand, showed there was no statistically significant difference that is (t (14) = .148, p = .884).

Table 14 – *Independent t-test analysis of fabric types and seam efficiency of a plain seam in a polyester poplin lining fabric*

Fabric direction/type		Mean	S.D.	df	*t* - value	*p* - value
	Warp					
	Kell Star	36.23	40.84	14	-2.226	.04*
Seam	Kell Special	76.98	31.84			
efficiency	**Weft**					
	Kell Star	27.38	29.86	14	.148	.88
	Kell Special	24.53	45.49			

Source: Field data, Quarcoo (2017), *Significant p < 0.05

In evaluating the mean scores, in the warp direction, Kell Special had higher seam efficiency (M = 76.98, SD = 31.84) than Kell Star (M = 36.23, SD = 40.84) but in the weft direction Kell Star was more efficient (M = 27.38, SD = 29.86) than Kell Special. The results for the weft direction indicate that Kell Special lining fabric is not as efficient as Kell Star lining fabric.

Research Hypothesis 5

H_{O5}: There is no significant difference between stitch densities with regard to seam efficiency of a plain seam in a polyester poplin lining fabric.

This section presents the results of the difference between stitch densities with regard to seam efficiency of a plain seam in a polyester poplin lining fabric, shown in Table 15.

Table 15 – *Independent sample t- test of stitch density and seam efficiency*

Fabric direction/SPI		Mean	S.D.	df	*t* - value	*p* - value
	Warp					
	SPI12	77.72	14.47	8	2.337	.047*
Seam efficiency	SPI15	35.49	49.01			
	Weft					
	SPI12	51.90	37.77	7	3.887	.006*
	SPI15	.00	.00			

Source: Field data, Quarcoo (2017), *Significant $p < 0.05$

Table 15 illustrates the results of independent t-test analysis of stitch densities and seam efficiency of a plain seam in a polyester poplin lining fabric. From Table 15, there was a statistically significant difference between 12 and 15 SPI in both the warp (t (8) = 2.337, p = .047) and weft directions (t (7) = 3.887, p = .006).

Research Hypothesis 6

$H_0$6: There is no significant difference between washing cycles (unwashed, first, second and third cycles) with regard to seam efficiency of a plain seam in a polyester poplin lining fabric.

To compare the differences between the washing cycles and seam efficiency, in both directions (warp and weft) of the fabric, one way analysis of variance was deemed appropriate for the analysis. However, prior to conducting ANOVA, certain assumptions need to be met. These include test for normality and homogeneity of variance. The results are presented in Table 16 and 17.

Table 16 – *Test of Homogeneity of Variances for washing cycles against seam efficiency*

	Levene Statistic	df1	df2	Sig.
Seam Efficiency	**Warp**			
	.014	3	12	.998
	Weft			
	2.358	3	12	.123

Source: Field data, Quarcoo (2017), *Significant p < 0.05

As depicted in Table 16, the sig value for the Levene test is .998 and .123 for the warp and weft respectively, which is more than the alpha value of p = 0.05. This implies that the homogeneity of variance has not been violated for the specimen test. That is, F (3, 12) = 0.014, p = .998 and F (3, 12) =2.358, p = .123 for the warp and weft respectively. Therefore, ANOVA test was also conducted.

Table 17 –*ANOVA results for washing cycles against Seam* Efficiency

	Variables	Sum of Squares	df	Mean Square	F	Sig.
Seam Efficiency	**Warp**					
	Between Groups	2720.11	3	906.71	.479	.703
	Within Groups	22693.95	12	1891.16		
	Total	25414.07	15			
	Weft					
	Between Groups	2779.569	3	926.523	.618	.616
	Within Groups	17979.90	12	1498.33		
	Total	20759.47	15			

Source: Field data, Quarcoo (2017), *Significant p < 0.05

Table 17 offers the results of the ANOVA test. The overall *F* ratio for the One-way ANOVA was not significant at the sig value of p = 0.05 in both the warp and weft directions. Looking at the results for the warp, it is clear that the F-ratio (0.479) is not significant (*p* =.703) at the 0.05 alpha level. Similarly, in the weft direction, there was no evidence off a statistically significant difference. It is obvious from the test that the F-ratio (.618) is not significant (*p* =.616) at the 0.05 alpha level. This means that there was no significant difference among the mean scores of the washing cycles with regards to their seam efficiency. Based on the analysis, the results confirm the null hypotheses stated as "There is no significant difference between washing cycles and seam efficiency".

Research Hypothesis 7

$H_0$7: There is no significant difference between fabric types with regard to seam elongation of a plain seam in a polyester poplin lining fabric

This section presents the results of the difference between fabric types with regard to seam elongation of a plain seam in a polyester poplin lining fabric shown in Table 18.

Table 18 shows the results of independent t-test analysis of fabric types and seam elongation of a plain seam in a polyester poplin lining fabric. From Table 18, there was no statistically significant difference between fabric types and seam elongation in the warp (t (12) = -1.650, p = .125) and weft directions (t (14) = 1.038, p = .317) of the fabric.

Table 18 – *Independent sample t – tests between seam elongation and fabric types*

Fabric direction/type		Mean	S.D.	df	*t* - value	*p* - value
	Warp					
	Kell Star	7.90	1.04	12	-1.650	.125
Seam	Kell Special	11.37	1.40			
elongation	**Weft**					
	Kell Star	11.96	12.96	14	1.038	.317
	Kell Special	5.79	10.72			

Source: Field data, Quarcoo (2017), *Significant p < 0.05

However, there was a difference in the means of the fabrics, with Kell Special having a greater seam elongation (M = 11.37 SD = 1.40) than Kell Star (M = 7.90, SD = 1.04) in the warp direction. In the weft direction on the other hand, Kell Star had greater elongation than Kell Special unlike the warp direction.

Research Hypothesis 8

$H_0$8: There is no significant difference between stitch densities with regard to seam elongation of a plain seam in a polyester poplin lining fabric

This section shows the difference between stitch densities with regard to seam elongation of a plain seam in a polyester poplin lining fabric presented in Table 19.

Table 19 – *Independent sample t - tests between stitch densities and seam elongation*

Fabric direction/SPI		Mean	S.D.	df	*t* - value	*p* - value
	Warp					
	12 SPI	14.17	1.18	7	3.299	.005*
Seam	15 SPI	5.38	7.44			
elongation	**Weft**					
	12 SPI	17.74	11.16	7	4.495	.003*
	15 SPI	.00	.00			

Source: Field data, Quarcoo (2017), *Significant $p < 0.05$

Table 19 displays the results of independent t-test analysis of stitch densities and seam elongation of a plain seam in polyester poplin lining fabric. From Table 19, there was a statistically significant difference between 12 SPI and 15 SPI for both warp ($t(7) = 3.299$, $p = .005$) and weft ($t(7) = 4.495$, $p = .003$) directions of the fabric. The results disagree with the null hypothesis which states that there is no statistically significant difference between the stitch densities with regard to seam elongation. Therefore, the null hypothesis was rejected. In both directions, 12 SPI experienced more elongation than 15 SPI.

Research Hypothesis 9

$H_0$9: There is no significant difference between washing cycles with regard to seam elongation of a plain seam in a polyester poplin lining fabric.

To compare the differences between the washing cycles and seam elongation, in both directions (warp and weft) of the fabric, one way analysis of variance was deemed appropriate for the analysis. However, prior to conducting ANOVA, certain assumptions need to be met. These include test for normality and homogeneity of variance. The results are presented in Table 20 and 21.

Table 20 – *Test of Homogeneity of Variances between washing cycles with regard to seam elongation*

	Levene Statistic	df1	df2	Sig.
Seam Elongation	**Warp**			
	.238	3	12	.868
	Weft			
	1.069	3	12	.399

Source: Field data, Quarcoo (2017), *Significant $p < 0.05$

Table 20, indicates that the sig, value for the Levene test is greater than the alpha value of $p = 0.05$ for both the warp ($p = .868$) and weft ($p = .399$) directions. This implies that the homogeneity of variance was not violated for the specimen test. Therefore, ANOVA test was also conducted.

Table 21 depicts the results of the ANOVA test for the study variable. It is palpable from the test that the F-ratio (.293) for the warp and the weft (.331) is not significant at the 0.05 alpha level. This means that there was no significant difference among the mean scores in the warp direction for the washing cycles with regards to their seam elongation. The results endorse the null hypotheses stated as "There is no significant difference between washing cycles and seam elongation".

Table 21 – *ANOVA results between washing cycles with regard to seam elongation*

	Variables	Sum of Squares	df	Mean Square	F	Sig.
Seam Elongation	**Warp**					
	Between Groups	48.26	3	16.09	.293	.829
	Within Groups	658.06	12	54.84		
	Total	706.32	15			
	Weft					
	Between Groups	162.87	3	54.29	.331	.803
	Within Groups	1969.24	12	164.10		
	Total	2132.11	15			

Source: Field data, Quarcoo (2017), *Significant $p < 0.05$

The results show that for both the warp $F(3, 12) = .293$, $p = .829$ and weft seams $F(3, 12) = .331$, $p = .803$, there was no statistically significant difference. Nonetheless, contrary to the findings of Danquah (2010), which indicated the seam elongation of the weft seams increased after washing, the current study showed that in the warp direction (weft seams), there was a downward slope to the percentage of elongation, indicating that the amount of elasticity the fabric possessed reduced with each washing cycle. The weft direction (warp seams) showed that the third washing cycle possessed the highest percentage of elongation.

Discussion

This section discusses the results of the study based on the research questions and hypothesis for the study.

Performance characteristics of fabrics

Research question one sought to find out the fabric performance qualities (yarn count, weight, linear density) of the two types of polyester poplin lining fabrics. According to Kadolph (2007), plain weaves usually employ half the number of picks per inch for the number of ends per inch. That is to say, the warp has more yarn count than the weft since the strain of a fabric falls on the warp. Per the findings, the warp direction of both Kell Star and Kell Special had more yarn count than that of the weft direction. Kell Special having more yarn count than Kell Star lining in both directions resulted in Kell Special having a higher weight. However, with regard to the yarn linear density, both Kell Star and Kell Special lining fabrics had equal Tex in the warp direction but in the weft direction Kell Special recorded a higher Tex than Kell Star.

The number of yarns in the warp being more than the number in the weft is no surprise since the findings showed that the warp threads for both Kell Star and Kell Special had greater strength than the weft threads. Therefore, the warp threads for both Kell Star and Kell Special showed less elongation as compared to the weft threads. The findings from the study lend support to the generally accepted fact that warp threads are stronger than weft threads and due to the strong nature of warp threads, the weft direction tends to have more elasticity than the warp direction . It is worthy to note however that, both fabrics were below the standard minimum requirement spelt out by the Ghana Standards Authority in GS 1032: 2013 in terms of their weight and breaking strength.

Influence of stitch density on seam strength

In research question two, the seam strength of polyester poplin lining when stitched with "OK" sewing thread at 12 and 15 SPI was determined. In the warp direction of Kell Star polyester poplin lining fabric, the strength of the unstitched fabric was more than the stitched fabric with 12 SPI. In the weft direction too, the unstitched fabric recorded higher strength than that of 12 SPI. Kell Special polyester poplin lining fabric also showed that the unstitched fabrics in both the warp and weft directions were of greater strengths than the specimen with 12 SPI. Specimens with stitch density of 15 could not be recorded because the seams were too tight causing the fabric to rapture while the seam was still intact. The weft specimen from Kell Star did not have fabric rupture, but rather the yarns slipped while the seam was still intact.

Corroborating this finding, American and Efird Inc., (2009) noted that on some light and medium weight fabrics, too many stitches tend to cause damage to the fabric. Since polyester poplin is a medium weight fabric, it explains why the Kell Special specimens stitched with 15 SPI underwent fabric damage. In the case of the weft specimens from Kell Star lining fabric, the slippage with intact seams can be attributed to the yarns being loosely woven. According to Carr and Latham (1994), seam slippage occurs in fabrics which have been made from yarns that are loosely woven. Schaeffer (2008) also asserted that loosely woven fabrics slip at stressed seams. As Kell Star lining fabric had less yarn count than Kell Special, it explains why it experienced slippage when stress was applied.

Influence of washing on fabric and seam strength

To find out if differences existed in the strength of the seams and fabric after three washing cycles, which answered Research Question three, means and standard deviations were employed.

For the weft seams, the results showed that throughout the three cycles of washing, the fabric (that is, the unstitched specimens) had a greater strength than the stitched specimens with 12 SPI. Specimens with 15 SPI could not be recorded since the seams did not rupture. For Kell Special lining fabric, the strength of the fabric was greater than the seam strength for both 12 and 15 SPI in all the cycles of washing. The seam strength of specimens with 15 SPI however, was greater than that of specimens with 12 SPI also in all the cycles of washing.

Warpwise, it was noted that for Kell Star lining fabric, the unstitched specimens (representing the fabric) in all the cycles of washing had more strength than the stitched specimens with 12 SPI. Similar to the weft seams, the warp seams with an SPI of 15 could also not be recorded due to tight stitches causing the seams to remain intact while the yarns slipped from the seam. For the warp seams of Kell Special lining fabric, the specimen with stitch density 12 recorded higher strength than the fabric. The first and second cycle of washing could however not be recorded due to fabric damage with intact seams. The third washing of the specimen also recorded a greater strength than the fabric, although the unwashed specimens with 12 SPI had the greatest seam strength. There was no record for 15 SPI due to fabric failure.

American and Efird (2002) indicated that normally high stitch densities have greater seam strength. Chowdhary and Poynor (2006) also stated that seam strength increased as stitch density increased and Ali, et. al., (2014), found from their experimental results that, with an increase in stitch density, the strength of the seam also increased but up to some extent, after which the strength of the seam decreased because the stitch density after a certain level caused the fabric to rupture. The findings from the study relate to the assertions of American and Efird and Chowdhary and Poynor because indeed the strength of the seams in the specimens stitched with 15 SPI were stronger than the specimens stitched with 15 SPI and therefore did not rupture in both types of lining fabrics. However, like Ali, et. al., 2014 pointed out, up to a certain extent the strength of the seams led to damage of the fabric after stress was applied.

Difference between fabric and seam elongation

The difference between fabric elongation and seam elongation after three washing cycles for the two polyester poplin lining types is what research question four sought to unearth. It is noted from the findings that, for both types of lining fabric, the weft direction specimens had more elasticity than the specimens in the warp direction. This finding is consistent with the generally accepted notion that yarns parallel to the weft direction almost always possess more elongation than those parallel to the warp yarns. It was also noted that for Kell Star lining fabric, the seam elongation was more than the fabric elongation for all the cycles of washing. Kell Special lining fabric also showed that specimens with 12 SPI had more elongation than the fabric as well as in the unwashed state than in the subsequent washing cycles. Stitch density 15 did not give as much as stitch density 12. This is attributed to the fact that 15 SPI had a firmer grip on the seams thereby reducing the elasticity of the seam. Chowdhary and Poynor (2006) observed in their study that an increase in seam density results in an increase in seam elongation. Similarly, Sarhan (2013) indicated in his study that seam elongation is augmented with an increase in stitch density. This was however not the case in the present study as Stitch density 15 did not give as much as stitch density 12. This is attributed to the fact that 15 SPI had a firmer grip on the seams thereby causing the fabric to rupture and thereby limiting the extent to which the seam could have been stretched.

Differences between fabric types and seam strength

Research hypothesis one stated that there is no significant difference between fabric types (Kell Star and Kell Special) with regard to seam strength of a plain seam in a polyester poplin lining fabric. The independent t-test analysis of fabric types and seam strength of a plain seam in a polyester poplin lining fabric showed that there is a statistically significant difference between the warp of Kell Star lining and Kell Special lining. Therefore, the null hypothesis was rejected. In the weft direction however, there was no statistically significant difference.

The findings corroborate with that of LaPere (2006) assertion that the strength of a fabric is dependent on its construction among other factors. As it has been established that warp threads are generally stronger, it is of no surprise that although the difference in the yarn count of the weft direction on both linings was more than the difference between the warp directions, the difference in strength was only significant in the warp.

Differences between stitch densities and seam strength

The null hypothesis in research hypothesis two stated that there is no significant difference between stitch density (12 SPI and 15) with regard to seam strength of a plain seam in a polyester poplin lining fabric. There was no statistically significant difference between stitch density 12 and stitch density 15 in the warp of the fabric. In the weft direction on the other hand, a statistically significant difference was apparent. This was due to the specimens with 15 SPI having no results as they did not experience seam rupture but rather fabric damage. The findings agree with Ali, et. al., 2014) as well as Danquah and Gavor (2016), who both identified from their studies that if a seam is stronger than the fabric it means that under stress the fabric will tear instead of the stitching, which will lead to a possible irreparable failure of the garment.

Differences between washing cycles and seam strength

To compare the differences between the washing cycles (unwashed, first wash, second wash and third wash) and seam strength, in both directions (warp and weft), in order to test hypothesis three, one way analysis of variance was deemed appropriate for the analysis. For both the warp and weft directions it was noted that there was no statistically significant difference between the washing cycles with regard to seam strength. These findings contradict the work of Mukhopadhyay, Sikka, & Karmaker, (2004), who postulated that the effect of laundering on seam tensile properties of suiting fabric was very significant and Shawky (2013), who also found out that there was a significant difference before and after 10 cycles of laundering cotton fabric. The contradiction between findings could be attributed to the number of washing cycles as well as the different types of fabrics used by Mukhopadhyay et al and Shawky.

Differences between fabric types and seam efficiency

In research hypothesis four, the results of independent t-test analysis of fabric types with regard to seam efficiency of a plain seam in a polyester poplin lining fabric revealed that there was a statistically significant difference between Kell Star and Kell Special in the warp direction but not in the weft direction. Evaluation of the mean scores also showed that in the warp direction, Kell Special had higher seam efficiency than Kell Star but in the weft direction Kell Star was more efficient than Kell Special. The results for the weft direction indicate that Kell Special lining fabric is not as efficient as Kell Star lining fabric.

The findings are as a result of a number of weft samples undergoing fabric damage. The results support the study by Akter and Khan (2015) on “the effect of stitch types and sewing thread types on seam strength for cotton apparel. In their study they found out that all stitches have higher seam efficiency in the warp direction compared to filling (weft) direction.

Differences between stitch densities and seam efficiency

The results of independent t-test analysis of stitch densities and seam efficiency of a plain seam in a polyester poplin lining fabric for research hypothesis five revealed there was a statistically significant difference between 12 and 15 SPI in both directions of the fabric. The findings reveal that as stitch density increased seam efficiency decreased. The findings are not consistent with what Chowdhary and Poynor (2006) and Sarhan (2013) who both postulated that higher seam efficiencies are associated with higher stitch densities. The contradictions between the present study and that of Sarhan and Chowdhary et al are due to the specimens with 15 SPI experiencing fabric rupture rather than seam rupture.

Differences between washing cycles and seam efficiency

In hypothesis six, the results from the analysis showed that there was no statistically significant difference between the washing cycles. Unlike Mukhopadhyay, Sikka, & Karmaker, (2004) who noted that the effects of washing on seam tensile properties of suiting fabric were significant; the results from the ANOVA test showed that in both the warp and weft directions, there was no statistically significant difference. However, another study by Viola and Ahuwan (2015) on the effects of laundering on seam efficiency of Nigerian wax-print fabrics (where four washing cycles were employed) also revealed that there is no statistically significant difference between washing cycles with regard to plain seams in Nigerian wax print. The differences can be attributed to the number of washing cycles and the type of fabric that was used in the study.

Differences between fabric types and seam elongation

In the seventh hypothesis, the results of independent t-test analysis of fabric types and seam elongation of a plain seam in a polyester poplin lining fabric showed that there was no statistically significant difference between fabric types and seam elongation in the warp and weft directions of the fabric. The results can be attributed to the fact that the linear density of the two fabrics as shown in Table 3 showed only slight differences.

However, there was a difference in the means of the fabrics, with Kell Special having a greater seam elongation than Kell Star in the warp direction. In the weft direction on the other hand, Kell Star had greater elongation than Kell Special. Again the difference in the means can be attributed to the yarn count of both types of fabrics. From Table 3, it is evident that Kell Special had more yarn count than Kell Star lining fabric, explaining why Kell Special had a greater elongation in the warp than Kell Star. The weft direction of the Kell Special fabric should have also had more elongation than Kell Star being that the yarn count was more with Kell Special but the results showed contrary evidence due to the fact that the weft specimen underwent fabric damage with intact seams and therefore a true representation of the elongation of the seam was not achieved.

Differences between stitch densities and seam elongation

The results of the independent t-test analysis of stitch densities and seam elongation of a plain seam in polyester poplin lining fabric for the eighth hypothesis showed that there was a statistically significant difference between 12 SPI and 15 SPI for both warp and weft directions of the fabric. The results disagree with the null hypothesis which states that there is no statistically significant difference between the stitch densities with regard to seam elongation. In both directions, 12 SPI experienced more elongation than 15 SPI.

The results were not consistent with the study by Chowdhary and Poynor (2006) and Danquah (2010) who noted differences between seam elongation and three stitch densities in both directions of the fabric they used for their study. They found that an increase in seam elongation was as a result of an increase in stitch density.

Differences between washing cycles and seam elongation

Hypothesis nine sought to compare the differences between the washing cycles and seam elongation, in both directions (warp and weft) of the fabric. The results of the ANOVA test for the study variable showed that the F-ratio for the warp and the weft was not significant at the 0.05 alpha level. This means that there was no significant difference among the mean scores in both directions of the fabrics after the washing cycles with regards to their seam elongation.

The results show that for both the warp and weft seams, there was no statistically significant difference. Nonetheless, contrary to the findings of Danquah (2010), which indicated the seam elongation of the weft seams increased after washing, the current study showed that in the warp direction (weft seams), there was a downward slope to the percentage of elongation, indicating that the amount of elasticity the fabric possessed reduced with each washing cycle. The weft direction (warp seams) showed that the third washing cycle possessed the highest percentage of elongation. This may be due to the possible removal of any form of fabric finishing which could have made the fabric brittle, thereby causing the yarns to become freer resulting in an increase in the percentage of elongation.

Chapter Summary

This chapter was in two sections; the results section where the findings were described and the discussion section where the results in the first section were discussed based on available literature. It discussed the performance characteristics of fabrics, influence of stitch density on seam strength, influence of washing on seam strength, difference between fabric and seam elongation, differences between fabric types and seam strength, differences between stitch densities and seam strength, differences between washing cycles and seam strength, differences between fabric types and seam efficiency, differences between stitch densities and seam efficiency, differences between washing cycles and seam efficiency, differences between fabric types and seam elongation, differences between stitch densities and seam elongation and differences between washing cycles and seam elongation. The next chapter summarizes the findings of the study, draws conclusions and considers any policy implications as well as suggestions for future research

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter presents a summary of the findings of the study as well as the conclusions, recommendations and directions for further research. That is, the chapter focuses on the implications of the findings from the study for policy formulation and further research. The recommendations are made based on the key findings and major conclusions arising from the study.

Summary of the Study

The purpose of the study was to investigate the influence of laundering and stitch density, on fabric and seam strength, elongation and efficiency of plain seams, in two types of polyester poplin linings sold on the Ghanaian market. To achieve this, experimental quantitative design was employed for the study. Two types of lining fabrics (Kell Star and Kell Special), two ranges of stitch density (12 SPI and 15) and three cycles of washing were used to carry out the investigation. The strip test method, a common tensile test method used to determine the breaking force and elongation of textile fabrics, was used in this study as indicated by ISO 13934-1(1999).

The instruments used in the collection of the data included an Ankerette® electric sewing machine, Standard Launder-Ometer (Gyrowash 315), tensile testing machine (OHAUS), magnifying glass, weighing balance (Adventure Pro) and a pair of scissors(see Appendix). The investigation was carried out in the School of Engineering Science (material science department) of the University of Ghana and Ghana Standards Authority Textile Testing laboratory. A total number of 135 specimens each were cut out of 3 yards each of polyester poplin lining fabric purchased. Descriptive statistics (means, standard deviations) and inferential statistics (independent sample t – test, one way ANOVA were used to analyze the data.

Key Findings

The results pertaining to research question one showed that Kell Star and Kell Special lining fabric have a greater yarn count in the warp direction than in the weft direction. Both lining fabrics also had equal yarn linear density in the warp direction but in the weft direction, Kell Special recorded a higher linear density. Overall, Kell Special weighed more than Kell Star lining fabric.

In the analysis of rupture, four types of deformation were observed; Rupture of seam, damage of fabric with intact seams, yarn slippage with intact seams and yarn slippage before seam rupture, which were labelled TYPE 1, 2, 3 and 4 respectively. Kell Star lining fabric experienced all the types of deformations. Kell Special on the other hand suffered only deformation TYPE 1 and 2.

It was unravelled that in the warp and weft directions of both types of fabric (Kell Star and Kell Special polyester poplin), the fabric (unstitched specimen) was of a greater strength than the seams with 12 SPI. Specimens with of 15SPI could however, not be recorded because the seams were too strong thereby causing the fabric to rapture while the seam was still intact

In the warp direction for both types of fabrics, there was no record for specimens with 15 SPI. Specimens with 12 SPI on the other hand, showed that the fabric was stronger than the seam for Kell Star and the seam was stronger than the fabric for Kell Special. In the weft direction, except for 15 SPI of Kell

Star, where there was no record, the fabric was of greater strength than the stitched specimens

For both types of lining fabrics, the weft direction specimens had more percentage elongation than the specimens in the warp direction. Both Kell Star and Kell Special lining fabrics possessed more seam elongation than fabric elongation.

There was a statistically significant difference between the warp of Kell Star lining and Kell special lining. The weft direction showed no statistical difference between the two lining fabrics.

There was no statistically significant difference between stitch density 12 and stitch density 15 for the warp direction of the fabric. However, the results showed that in the weft direction, there was a statistically significant difference between the stitch densities.

In relation to washing cycles, the results showed that there was no significant difference among the washing cycles with regards to their seam strength in the warp direction. Also, in the weft direction, results showed that there was no significant difference among the washing cycles with regards to their seam.

There was a statistically significant difference between Kell Star and Kell Special in the warp direction. The weft direction showed that there was no statistically significant difference. In evaluating the means scores for the warp direction, Kell Special had higher seam efficiency than Kell Star but in the weft direction Kell Star was more efficient.

The results showed that there was a statistically significant difference between 12 and 15 SPI in both the warp and weft directions. The findings revealed that as stitch density increased seam efficiency decreased.

The results again showed that there was no significant difference in washing cycles with regards to their seam efficiency. However, in the warp direction (weft seams) the mean scores showed a downward decline in seam efficiency with each washing cycle.

There was no statistically significant difference between fabric types and seam elongation in the warp and weft directions of the fabric. Nonetheless, there was a difference in the means of the fabrics, with Kell Special having a greater seam elongation than Kell Star in the warp direction. In the weft direction on the other hand, Kell Star had greater elongation than Kell Special.

There was no significant difference among the washing cycles with regards to their seam elongation in both warp and weft direction. Nonetheless, the study revealed that in the warp direction (weft seams), there was a downward slope to the percentage of elongation, indicating that the amount of elasticity the fabric possessed reduced with each washing cycle. The weft direction (warp seams) showed that the third washing cycle possessed the highest percentage of elongation.

Conclusions

Based on the findings of the study, the following basic conclusions are drawn. The general performance of seams in a constructed apparel depend largely on the direction of the seams in the fabric, the stitch density employed as well as how often the clothing is washed. The strength, elongation and efficiency of seams depend on the type of fabric and stitch density used. The fabrics used for the study had greater strengths than the seams due to the stitch densities which were employed. In a nut shell, although some of the seams ruptured, both stitch densities were too strong for the fabrics thereby causing slippage in Kell Star and fabric damage in Kell Special lining fabrics. The fabrics of both Kell Star and Kell Special were stronger than the stitched samples in 12 SPI except for 15 SPI where the seam was stronger thereby causing damage to the fabric. The strength of the fabric declined after each washing cycle with a shoot up after the third washing cycle.

Recommendations

Based on the findings from the study, the following recommendations are hereby made;

In the first place, I recommend that the Ghana Standards Authority should enforce the standards that have been made on woven lining fabrics. This should be done by ensuring that the lining fabrics that are imported meet the required standards before entering the market, to enable consumers be assured of the quality of lining fabrics on the market. This would help consumers achieve desired results from fabrics purchased.

Again, I recommend that seamstresses and tailors should be advised through outreach programmes, seminars, workshops and conferences by Home Economics Departments and stakeholders in the garment industry in Ghana, to use appropriate stitch densities in the construction of garments; since some of the garment makers select stitch densities and lining fabrics without paying attention to their effect on the overall performance of the apparel being made, since they can interact with the processes garments go through to influence their seam performance.

Suggestions for Further Research

The researcher suggest the following for further studies

1. An attempt should be made to investigate the performance of seams in other lining fabrics by varying stitch densities, and care procedures such as ironing and laundry. This will give an overall picture of the performance of seams in lining fabrics.
2. Again, in further studies, I recommend that the number of washing cycles should be increased in order for a more significant difference to be realized.

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APPENDICES

APPENDIX A: SPECIMEN CUT 25MM ×120MM AND FRAYED ON BOTH SIDES

APPENDIX B: RUPTURE OF SEAM (TYPE 1)

APPENDIX C: DAMAGE OF FABRIC WITH SEAM STILL INTACT

(TYPE 2)

APPENDIX D: YARN SLIPPAGE WITH SEAM INTACT (TYPE 3)

APPENDIX E: YARN SLIPPAGE AND SEAM RUPTURE (TYPE 4)

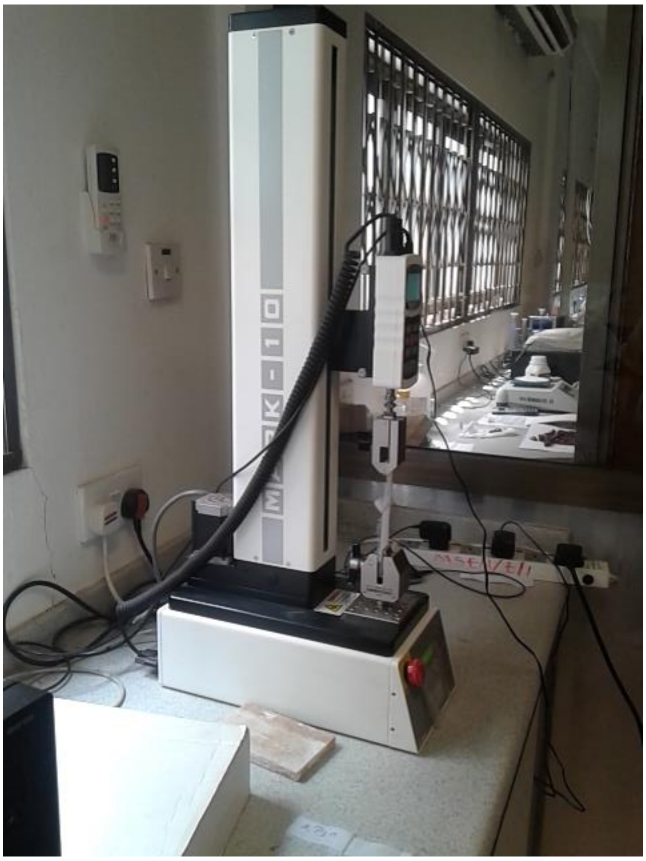
APPENDIX F: MAGNIFYING GLASS

APPENDIX G: OUTSIDE OF GYROWASH

APPENDIX H: INSIDE OF GYROWASH WITH CYLINDERS

APPENDIX I: WEIGHING BALANCE

APPENDIX J: TENSILE TESTING MACHINE



APPENDIX K: INTRODUCTORY LETTER TO UNIVERSITY OF GHANA

UNIVERSITY OF CAPE COAST
CAPE COAST, GHANA
COLLEGE OF EDUCATION STUDIES
FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION
DEPARTMENT OF VOCATIONAL AND *TECHNICAL EDUCATION*

Telephone: 024-32440-9 & 32480-9 Ext. 262
Direct: 03321-**33803**
TELEX: 2552, UCC, GH.

University Post Office

VTE/1.7/VOL.2/11

19th December, 2016

The Head
Department of Material Science
School of Engineering
University of Ghana

Dear Sir,

INTODUCTORY LETTER

We have the pleasure of introducing to you Esther Quarcoo who is an M.Phil. student at the Department.

We would be very grateful if you could grant her the use of your laboratory and tensile test machine for her thesis work on the topic **"Seam Performance of two Types of Polyester Poplin Used as Lining on the Ghanaian Market'**

Thank you.

Yours faithfully,

Boateng

Dr.(Mrs.) Christina Boateng
HEAD OF DEPARTMENT

APPENDIX L: INTRODUCTORY LETTER TO GHANA STANDARDS AUTHORITY

UNIVERSITY OF CAPE COAST
CAPE COAST, GHANA
COLLEGE OF EDUCATION STUDIES
FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION
DEPARTMENT OF VOCATIONAL AND *TECHNICAL EDUCATION*

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Direct: 03321-**33803**
TELEX: 2552, UCC, GH.

University Post Office

VTE/1.7/VOL.2/7

19th December, 2016

The Director of Testing
Ghana Standard Authority
Greater Accra.

Dear Sir,

INTRODUCTORY LETTER

We have the pleasure of introducing to you Esther Quarcoo who is an M.Phil. student at the Department.

We would be very grateful if you could grant her the use of your laboratory and equipment for her thesis work on the topic **"Seam Performance of two Types of Polyester Poplin Used as Lining on the Ghanaian Market.'**

Thank you.

Yours faithfully,

Boateng

Dr.(Mrs.) Christina Boateng
HEAD OF DEPARTMENT

APPENDIX M: REQUEST FOR ANALYSIS FORM (PAGE 1)

Page 1 of 2

GHANA STANDARDS AUTHORITY

FORM

TITLE: Request For Analysis Form **Doc. No.: TES-PPC-HOD-FM-001-1**

FOR OFFICIAL USE ONLY

LAB NO: C40-B41/M152/12	~~640/M152/12~~
REQUEST IDENTIFICATION (File Ref.)	
URGENCY CLASS:	D
DATE:	17-02-14

Dear Sir / Madam,

Please analyse / test the following samples:

IDENTITY/TYPE OF SAMPLE	NO. OF UNITS/QUANTITY	PACKAGING
Lining fabrics 1. White x2	2 yds each	

History (Sample): From ~~Shoe~~ Client

Analysis required are:

PARAMETER	REF. TEST ~~METHOD~~ / REF. STD. SPEC.
colourfastness to washing	

Purpose for requesting this analysis: (Circle one)

Certification/Factory Quality Audit/Market Quality Audit/Special Request/Complaint/ Quality Evaluation/ Determine Wholesomeness or Spoilage/Develop or re-formulate product/Obtain Customs Clearance/ Prosecute a Criminal (underline as appropriate)

Yours truly,

(SIGNATURE): Esther

TITLE OR POSITION IN COMPANY: Student

NAME IN FULL: Esther Quarcoo

NAME OF COMPANY: University of Cape Coast

ADDRESS OF COMPANY: Cape Coast Ghana

TELEPHONE NO: 0244677470

APPENDIX N: REQUEST FOR ANALYSIS FORM (PAGE 2)

Page 2 of 2

GHANA STANDARDS AUTHORITY

FORM

TITLE: Request For Analysis Form **Doc. No.: TES-PPC-HOD-FM-001-1**

DISCUSSION WITH CLIENT (TO BE FILED BY GSA OFFICER)

1. Purpose of Test Research
   Is the purpose as indicated over leaf clear?
   If not, provide more information.

2. ESSENTIAL PARAMETERS TO BE TESTED FOR:
   Is request clear? Yes
   What other parameters do you recommend?

3. Nature of sample and recommended storage conditions: Ambient

4. Adequacy of sample(s) Adequate

5. Recommended Fees ¢200.00

6. Other remarks

7. Urgency Classes
   a) Very Urgent (Analysis and Test should be finished within 5 days)
   b) Urgent (Analysis and Test should be finished within two weeks)
   c) Normal (Analysis and Test should be finished within 3 weeks)
   d) Investigations/ Surveys

8. Mode of Despatch To be collected by client

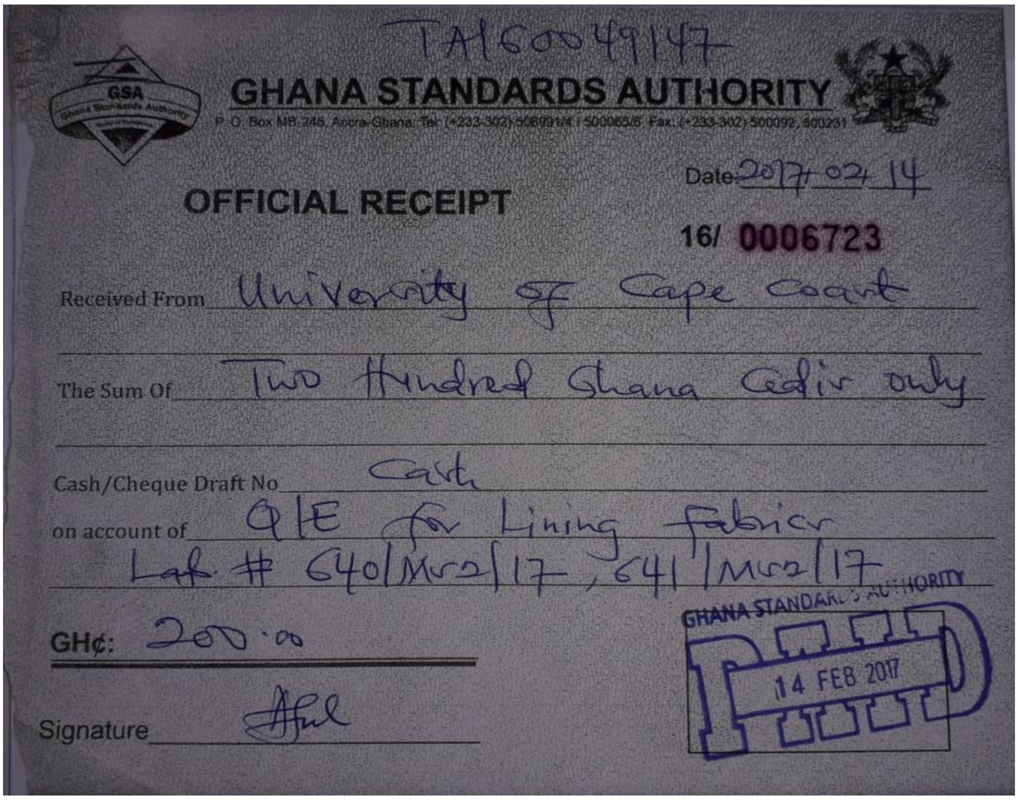
   It is recommended that all:

   i) Customs/Police samples are classified as URGENT (b)
   ii) Inspectorate samples are classified as NORMAL
   iii) General Govt/ Hospitals are classified as VERY URGENT (a)

NAME OF GSA OFFICER: Rachel Amankwa

SIGNATURE: .... **DATE:** 17-02-14

APPENDIX O: RECEIPT FROM GHANA STANDARDS AUTHORITY



TA160049147

GHANA STANDARDS AUTHORITY

P. O. Box MB 245, Accra-Ghana. Tel: (+233-302) 506991/4 / 500065/6 Fax: (+233-302) 500092, 500231

Date: 2017-02-14

OFFICIAL RECEIPT

16/ 0006723

Received From University of Cape Coast

The Sum Of Two Hundred Ghana Cedis only

Cash/Cheque Draft No Cash

on account of Q/E for Lining fabrics

Lab # 640/M02/17, 641/M02/17

GH¢: 200.00

Signature

GHANA STANDARDS AUTHORITY
PAID
14 FEB 2017