ABSTRACT

STANHOPE, CLAIRE MARGARET. Acceptance of Bast Fiber Textiles for Sustainable Product Development. (Under the direction of Dr. Lisa Parrillo Chapman, Dr. Katherine Carroll, and Dr. Trevor Little).

This research provided a foundation for bast fibers to be utilized as high value products in the apparel industry. The objective of this research is to demonstrate the potential for bast fibers to be accepted into the textile industry as a sustainable material. The research determined potential uses of bast fibers as well as their acceptance by the consumer through judgment of their sensory perception. This research also aimed to determine general opinions and attitudes from industry members towards these fibers in the development of end products such as apparel.

The research objective was accomplished through two phases. Phase One of the research was to conduct informal interviews with three companies in the textile industry, specifically companies who hold sustainability with high importance and/or who work within the apparel production industry. The interviews determined what their views on bast fiber are, do they use bast fibers in their products, and what they think about the potential for bast fibers in the textiles industry. Phase Two of the research adapted and utilized a material testing procedure to determine sensory perception of these materials compared to one another, and to other materials, through a physical fabric hand evaluation procedure.

The sample that participated in the evaluation of sensory perception of fabrics consisted of 102 male and female subjects primarily from the central North Carolina region. Data supported the following conclusions regarding rating and ranking of the bast fiber fabrics. Overall Fabric E, the recycled polyester/organic cotton blend, was

rated most comfortable over the other fabrics. However, Fabric B and C, the two pure bast fiber fabrics, were still rated as comfortable, and were preferred over the other fabrics for other product categories. Fabric B rated best for fashion tops and dresses. Fabric B also rated among the best for kitchen textiles such as table cloths, and napkins. Fabric C was rated best among the fabrics for accessories (primarily scarves), and undergarments, which denotes the acceptance of wearing these fabrics close to the skin. Fabric C also rated highest in the other category, which consisted of beach cover-ups, sheer apparel, fashion garments, and children's apparel. Fabric E, although rated highest among comfort category, and rated top for ranking category for use in a tee shirt, rated highest in only the pajama category, while Fabric D was chosen the most for a tee shit as the end product and for bedding. Fabric A, Cotton/hemp blend voted best for outerwear and rated highest for home furnishings.

Overall considering the company interviews, and the survey results, bast fibers have a viable place in the market. Further developments in processing and availability would only help to increase the potential for these fibers. Education for both the consumer and product developers on the importance of using sustainable materials could also help drive the demand for these materials.

This research aimed to demonstrate the possibility, advantages, and disadvantages for product developers to incorporate bast fiber materials into their product development process' to achieve more sustainable products. This research will benefit textile companies wishing to implement more sustainable initiatives into their business such as using more sustainable materials. This research could also benefit farmers wanting to incorporate more diversity into their crops, or to participate in sustainable agriculture. The results of this study could also be beneficial to product developers to show the properties of bast fibers, and to potentially influence designers and product developers to make more sustainable material choices.

Acceptance of Bast Fiber Textiles for Sustainable Product Development

by
Claire Margaret Stanhope

A thesis submitted to the Graduate Faculty of
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requirements for the Degree of
Master of Science

Textiles

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APPROVED BY:

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Dr. Lisa Parrillo Chapman Dr. Trevor Little
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Dr. Katherine Carroll

DEDICATION

To Mom and Papa,

For continued love and encouragement

To Sam,

For unconditional love and understanding

You keep me grounded and balanced

To Meta,

For reminding me to live each day to the fullest

BIOGRAPHY

Claire Stanhope was born in Honolulu, Hawai'i on October 15^{th}, 1986 to William and Jane Stanhope. She has one older brother, Christopher Stanhope. Claire moved from Hawai'i to live, for two years, in Algeria where her parents had started a school. From the beginning, Claire's parents instilled a love for the earth, for travel, and for aesthetics. This has aided in helping pave her path thus far. Claire grew up predominantly in Asheville, North Carolina. During her time in high school, Claire attended a study abroad program in France, where she learned French and furthered her adventurous spirit.

In 2005, after graduation from Asheville High School, Claire was accepted to the College of Textiles at North Carolina State University, where she earned her degree in Fashion and Textile Management and Product Development, as well as a minor in French Foreign Language. During this time Claire participated in many fashion shows and fabric design competitions, in which she earned several awards. After completing her undergraduate studies at NC State in 2009 Claire decided to further her education in a field that she felt passionate about. She was accepted to North Carolina State University's Masters of Science program and began her research in sustainable design in textiles and product development.

After completing her Masters of Science, Claire hopes to combine her passion for creativity with her conviction that sustainability is the only path forward in industry. She wants to be instrumental in facilitating new consciousness within the framework of industrial practices that will not only have a positive impact on the environment but will provide the positive business model demanded in a world of diminishing resources.

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CHAPTER 1: INTRODUCTION

Tamsin Blanchard, author of *Green is the New Black* (2007), says "the best fashion reflects the time we live in". This statement holds true in our present world, whose resources are being depleted but which the textiles industry intends to move in a more sustainable direction (Blanchard, 2007).

As companies contemplate the implementation of a more sustainable industry, one of the most important elements is making the change to more sustainable materials and processing techniques that are used to manufacture textiles. As early as 1970, Victor Papanek saw the role designers could play to lessen the negative environmental impact of the textile industry. He said that in this age of mass production, designers have become the most powerful shapers of our work and environments (Papanek, 1971). Because product developers and designers have the ability to select materials, they have the ability to determine how sustainable the final product is. Many designers assume that their area of responsibility lies only in the function and appearance of a product. Designers often have a stigma connecting sustainable materials with poorer perception of fabric hand, this is why it is important to demonstrate the attributes of sustainable materials through a subjective assessment of fabric hand. Sometimes the values and attributes of luxury are perceived as conflicting with the values and attributes of sustainable design. This study aimed to assess the evaluator's satisfaction with sustainable materials compared to other more commonly used and less sustainable materials.

Cotton fibers are 48% of the worldwide consumption of natural fibers, while synthetic fibers make up approximately 45% of the worldwide demand for fibers overall. Both natural and synthetic fibers have positive and negative attributes when considering sustainability (Pimentel et al., 1991; WWF, 1999). For example, synthetic fibers deplete nonrenewable fossil resources, while cotton cultivation is coupled with high water requirements and the use of considerable amounts of pesticides and fertilizers (Turunen, L, et al., 2006). Because a high demand for raw materials is counteracting the move towards a more sustainable future, alternative resources, such as non-cotton natural fibers, could contribute importantly to the sustainability of the textile industry (Turunen, L., et al., 2006).

Natural fibers are a viable choice for textile product development when considering a renewable and environmentally acceptable material. However, the vast array of natural fibers and the variance in the physical properties of each fiber can make choosing the correct fiber difficult. Furthermore, newly developed fiber and yarn processes for natural fibers add to the complexity level in product development decisions. In order to aid product development decisions this body of research seeks to develop a descriptive method for assessing the physical characteristics of natural fibers. Natural fibers cover a broad range of vegetable, animal, and mineral fibers (See Table 1), and the distinct physical characteristics of each type can be exploited to improve the functional and aesthetic properties of a product. This research highlighted the natural fibers that fall under the bast fiber category and demonstrated the properties and possible end uses for bast fibers in the textile industry associated with sensory perception.

Table 1. Natural fibers

Animal fibers	**Cellulosic fibers**				
	Bast Fibers	Leaf Fibers	Seed Fibers	Fruit Fibers	Wood Fibers
Wool	Flax	Sisal	Cotton	Coconut	Pine
Silk	Hemp	Curana	Kapok		
Hair	Kenaf	Banana			
	Jute	Pineapple			
	Ramie				
	Tobacco				

Note: Table adapted from ASTM 07641

1.1 Objective of the Study

The objective of this research is to demonstrate the potential for bast fibers to be accepted into the textile industry as a sustainable material. The research determined potential uses of bast fibers as well as their acceptance by the consumer through judgment of their sensory perception. This research also aimed to determine general opinions and attitudes from industry members towards these fibers in the development of end products such as apparel.

The research objective was accomplished through two phases. Phase One of the research was to conduct informal interviews with several companies in the textile industry, specifically companies who hold sustainability with high importance and/or who work within the apparel production industry. The interviews determined what their views on bast fiber are, do they use bast fibers in their products, and what they think about the potential for bast fibers in the textiles industry. Phase One also helped to facilitate the evaluation procedure in Phase Two, by determining the fabric types and end product that were used.

Phase Two of the research adapted and utilized a material testing procedure to determine sensory perception of these materials compared to one another, and to other materials, through a physical fabric hand evaluation procedure.

This research aimed to demonstrate the possibility, advantages and disadvantages for a product developer to incorporate bast fiber materials into their product development process to achieve a more sustainable product.

1.2 Relevance

Sustainability throughout any industry is becoming increasingly relevant in today's society. With the depletion of resources, it is important to consider the effects of production and consumption habits on the environment. Sustainability is a systemic concept, relating to the continuity of economic, social, and environmental aspects of human society. It is defined as society, its members, and economies being able to meet the needs and greatest potential in the present, while preserving resources, biodiversity, and natural ecosystems in a sustainable manner for future use (Bruntland Commission, 1987).

Though they are far from being the mainstream in the textile industry, the advancement and popularity of some bast fibers is inevitable. Improvements are constantly being made to advance processing procedures, improve properties, and increase popularity at a commercial and industrial level. However, there is little published information available on the expected response and long-term success of bast fibers on the product developer and consumer end of the spectrum. This study aimed to provide insight into the behaviors and opinions surrounding bast fiber textile products. The research will identify consumer response to the use of bast fiber textiles in common apparel products and purchase intentions through the evaluator's perception of hand.

The results of this study could be significant to manufacturing companies of textile products and will help them to better align their product with the demand for a more sustainable industry. The results of this study could also be beneficial to product developers to show the properties of bast fibers, and to hopefully influence designers and product developers to make more sustainable material choices.

This research could also be beneficial to farmers who want to participate in sustainable agriculture, or who want to diversify their crops.

CHAPTER 2: LITERATURE REVIEW

2.1 Bast Fiber Overview

Hemp, flax, jute, kenaf, ramie, and tobacco plants are all producers of bast fibers, which mean that the fiber is predominantly located beneath the bark of the plant stalk, otherwise known as the phloem (Alex, R. et. al. 2004). The fibers are found within the inner bark of the stem/stalk of the plant and in the woody core. This structure in turn, necessitates a different way of extracting and processing the fibers (Clemons & Caulfield, 2005). Bast fibers often have fibers that demonstrate varied properties and are located in the very center core of the stalk. Figure 1 demonstrates the makeup of the bast fiber. Bast fibers are a natural and renewable resource that can be used in textile products, but, just as with any natural material, there is a variance found from crop to crop. The mechanical properties of bast fibers are influenced by the variety grown, the growth and weather conditions, the date of harvest, the degree of ripeness at harvest, and the retting procedure as well as the decortication (which will be explained later), processing, and cleaning processes (Munder et al., 2006).

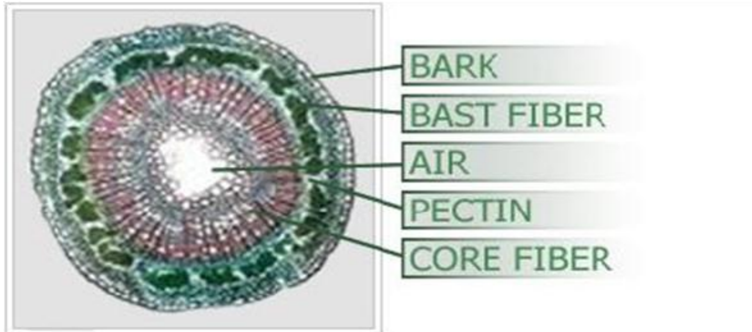

Figure 1: Makeup of a bast fiber
(Image: Bastfibersllc.com, 2011)

Bast fibers can be grown in moderate climates and need less input than other natural fibers to give high yields. The hemicellulose content of these fibers contributes to the properties of breathability and thermal insulation, both of which are excellent features in textiles. Bast fibers traditionally have been used for twine, rope, or burlap, and the fiber is gradually being incorporated back into the textile industry as new uses are being discovered. From the sixteenth through the eighteenth century flax and hemp were major fiber crops used for the production of fabrics for garments. The used and worn out fabrics were recycled and used as raw materials for paper mills. These fibers were slowly replaced with large scale cultivation of cotton and other fibers, as well as new technologies that processed wood into pulp for paper products (Van der Werf et. al., 1996). Almost all textiles are now derived from synthetic or cotton fibers. Other natural fibers such as silk, wool, and bast plant fibers comprise only a small percentage of the textile market. People are now becoming more aware of the complications associated with cotton cultivation; its restriction to sub-tropical climates, its dependence on high amounts of water, and the requirement of extensive agrochemicals to ensure good yields (Ebskamp, 2002).

2.1.1 Bast Fiber Processing**:**

One of the limitations of using bast fibers is the process of separating the bast fibers from the outer stems. In order for bast fibers to be used in textile applications, the fibers must be separated from the rest of the stalk using a microbial process, known as retting, that breaks the chemical bonds between the bast fibers and the woody core (USDA, 2000). Retting can occur by two distinctly different commercial processes, *water retting*, or *dew retting*. Dew retting is also referred to as field retting (Jhala, 2010). Harvesting and fiber processing differ depending on the intended end use of the crop. For example, if the plant is being cultivated for high-quality textile fibers, the crop must be harvested when it is at its highest quality. For field retting, the crop is cut by specialized equipment that lays the plants in rows and then leaves them in the field to rot. Farmers monitor this process in order to make sure the fibers separate without damage or deterioration of fiber quality. Dew-retting can cause a wide range of variation of the mechanical properties of the fibers. This is due to biological-bacteriological changes of the material that are not always kept under constant control (Munder et. al., 2006). Although weather conditions affect the quality of the fiber acquired (moisture is needed for the rotting, but dryness is needed for baling of the stalks), this process is used extensively because of its low cost and low usage of water.

Water retting produces a more uniform and higher quality fiber, but the process is less environmentally friendly and is more capital and labor intensive than dew retting. The process involves submerging the crop into water and consistently monitoring the separation process. This process uses large volumes of clean water, which must be treated before discharging in lakes, streams, and ground water because of the pollution from anaerobic decomposition. Another limitation to water retting is the high cost of drying the stems. Water retting has been largely discontinued because of environmental regulations in most countries and high capital needed for the process (Jhala, 2010). The water retting process is used in countries with no environmental regulations, such as China and Hungary, but this retting process is decreasing with the increased usage of microorganisms or direct use of enzymes to separate the bast fibers from the woody core (USDA, 2000).

After the retting process is finished, a machine is then used to gather and tie the stems into bundles for pickup and delivery into the mill. These systems are designed to maintain parallel alignment throughout harvesting and processing in order to recover the longest and highest quality textile fibers (USDA, 2000). Once the fibers are retted, dried and baled, they are ready to be processed into fibers. This process uses a decorticator to separate hurds (short pieces of the woody core), tow (broken or short fibers), and the longer remaining bast fibers (line fiber). In the natural state, the fibers within the stalk are cemented by an inter-cellular substance, which consists of lignin and pectin. This cementation is dissolved during the decortication process in order to separate the bundles of fibers (Mundel et. al., 2006).

Although the decortication process is partially mechanized it is very similar to the traditional hand methods of preparing hemp or flax for twisting into twine or rope. It is time consuming, requires skilled workers and considerable capital investment in equipment. Figure 2 demonstrates an overview of three alternative fiber processing scenarios for hemp fiber.

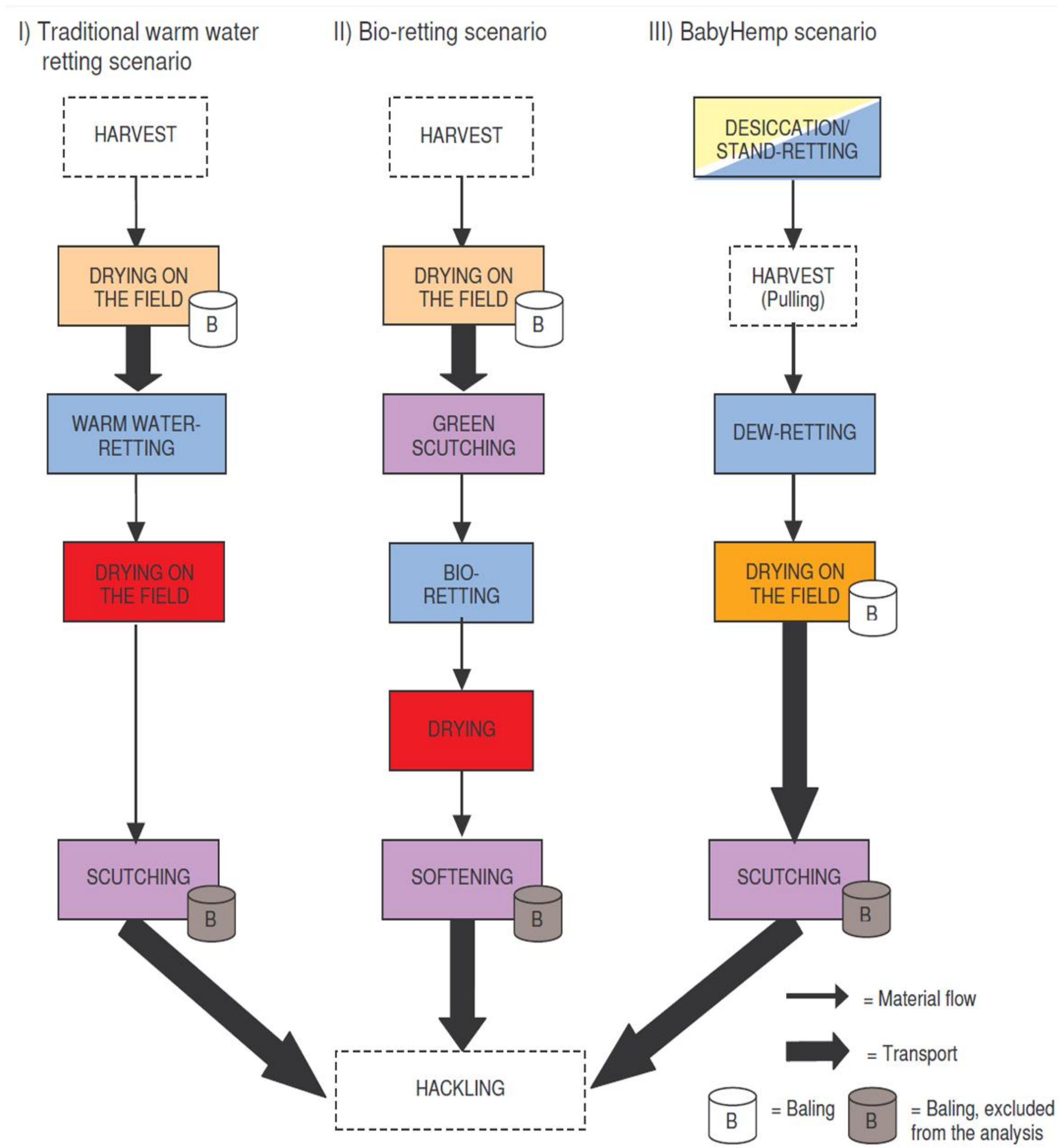

Figure 2: Bast fiber processing overview
Note: (J. Turunen, L., Van der Werf, H., 2006)

Research has been conducted to further improve systems to separate and process bast fibers in order to lower the environmental impact and to maintain the quality of fiber for textile production. Van der Werf et al. (2007) conducted a study to identify the environmental impacts of the production of hemp fiber. They focused on the traditional warm water retting production process compared to bio retting, baby hemp, and dew retting of flax. Bio retting is a process similar to warm water retting, but instead of relying on natural bacteria, an inoculum of selected pectinolytic bacteria is added to the water to aid in the retting process. In the baby hemp scenario, the processing stage overlaps with crop production. Desiccation, which is part of the baby hemp harvesting technique, terminates crop growth and encourages *stand retting*. The crop is left in the field for approximately 30-50 days, which begins the retting process in the stems. The stems are then pulled and left in the field to dry; additional time is given to stimulate dew retting (Turunen, L.,& Van Der Werf, H, 2006). This project aimed to develop and measure the environmental impacts of hemp cultivation and intended to develop an improved sustainable production chain for high quality hemp fiber textiles. Using the Life Cycle Assessment (LCA), the impacts of the hemp and flax cultivation were measured through resources consumed and emissions released into the environment through every step of the products life cycle. This assessment measured three stages; 1) crop production, 2) production of long fiber and yarn production, and 3) product resources, which include the use of the product and the reuse, recycle ability, and/or final disposal. Aspects of this study that were incorporated in the sustainability portion included inputs used for field production (ammonium nitrate, pesticides, diesel, seed for sowing etc), yield per hectare, land occupation, emissions due to electricity use, climate change, eutrophication (the addition of artificial or non-artificial substances, such as nitrates and phosphates, through fertilizers or sewage, to a fresh water system), non-renewable energy use, acidification, crop production, fiber processing stages, and nitrate leaching (all measures per 100kg of yarn produced) (Van de Werf et. all, 2007).

The results of the Van der Werf et. all's study showed that hemp bio retting had higher impacts than hemp warm water retting for all aspects except eutrophication and pesticide use. The hemp bio retting uses more energy consumption in fiber processing, resulting in climate change and acidification. The heating of the water for the retting as well as drying uses more energy than the traditional practice of using naturally warm water and drying on the field. The cultivation of babyhemp, as opposed to the traditional water retting, had higher values in all impacts except water usage, due to significantly lower yield (3.25 tons/ha, compared to 6.5 tons/ha for water retting hemp)(Van der Werf et al., 2007). Hemp bio retting compared to babyhemp cultivation had higher values for energy use, climate change, acidification and water use because its fiber processing stage is more energy intensive. Babyhemp cultivation had higher eutrophication and land occupation impacts due to its low yield and increased pesticide usage. Flax dew retting was comparable to the warm water retting of hemp in all aspects except eutrophication, water use, and pesticide use. Eutrophication decreased because no effluents are involved, the flax cultivation involves less water consumption (because water is used only in the rove bleaching), and pesticide use is increased (Van der Werf et. all, 2007). In conclusion, the study determined that the most energy was consumed during the yarn production of the hemp and flax fibers, which is evidence that this aspect of the production process could be improved in order to include technological developments to produce more efficient processing systems (Van der Werf et. all, 2007).

The research of Alex et. al., (Sustainability and Profitability through Intelligent Value Chain Management in Bast Fiber Processing, 2004), explored different methods for separating bast fibers that forgo traditional retting and scutching. This study was conducted in Reutlingen, Germany at the Reutlingen University, in the hopes of expanding the production of bast fibers in the European market. Alex explored steam explosion treatment as a possible processing method to reach the goals of entering high value applications for bast fibers. Steam Explosion Treatment (STEX) is an example of wet processing that aids in making hemp a more commercially viable fiber as far as the properties of the fiber and yarn. The outlook for the fiber upgrading business using the STEX method is promising and is shown in this study by a strategic model and by an operational business calculation. As described in the results of this study, the inclusion of wet processing gives a positive return on investment, because it offers improved fiber quality as well as product differentiation for new applications in both fashion and high performance composites (Kessler,2000). In order to measure the benefits of certain added steps in the processing chain, ecological challenges and benefits must be kept in mind; "i.e. growth of population, future energy demand, greenhouse effect and destruction of the ozone layer, profitability, and sustainability in agriculture" (Alex et al., 2004). Alex et al. (2004) suggest creating a network linking farmers, fiber refining companies, upgraders, spinners and weaving firms. Keeping all stakeholders involved in the process of creating a better, more sustainable product, is more likely to insure the most equitable practices for each step in the production chain resulting in a 'win win' solution. This retting system is said to guarantee consistent industrial supply, high quality manufacturing, reasonable price policies, and consumer acceptance of the product. This specific study focused on production of 50% hemp/50% cotton jeans and results showed that a sustainable and profitable system in bast fiber processing is possible and can provide fair and competitive prices to all involved (farmers and processors) on the condition that the market is willing to accept slightly higher production costs for improved durability, better comfort, and exclusive fabric (Alex et al., 2004). Other possible processing procedures that exclude the retting process which include, steam explosion, ultrasonic treatment, enzymatic degumming, or chemical processing, are currently in the R&D phase. Each of these processing procedures creates different fiber parameters and properties, making quality assurance one of the main challenges associated with natural fiber production (Munder et al., 2006).

2.2. Flax

2.2.1 History/Development

Flax, known commonly as linen in the fabric form, is one of the oldest fibers used in textile production as well as in other forms of production such as flax seed for consumption. Flax that is cultivated for textile fibers is primarily grown in Northwest Europe (traditionally northern France, Belgium, and Holland), Eastern Europe, Belorussia, Russia, China, Egypt, and in small quantities in other countries such as Brazil and Chile. The art of using the flax crop as a fiber for weaving dates back many years and was used for winding clothes to prepare the bodies of the pharaohs for burial. Flax was then introduced to India, where many tribes, before the introduction of cotton, popularly wore linen. The colonists, who brought it over for fiber, introduced flax to the United States. As the production of cotton increased and the invention of the cotton gin arrived, the use of flax for linen for textiles declined (Jhala et al., 2010).

Similarly to other bast plants, the fibers of flax are found in the phloem of the stalk, which surrounds the woody center. The best period to obtain ultimate quantity and quality of fibers within the stalk is at the end of flowering, at which point 25% of the dry weight of the flax stalk is represented by fibers. One limitation of flax is the separation of bast fibers from other parts of the stem. Traditionally, this was accomplished by a retting process. The two traditional retting processes that were used were water-retting and dew-retting. Water retting, as discussed earlier, has been discontinued because of its high cost and pollution output. Dew-retting has its limitations as well, including poor quality fiber and weather temperature restrictions. In the 1980's efforts were made to overcome these limitations. A new method was developed known as enzyme retting, which replaced the anaerobic bacteria with enzymes. This new method reduced retting time, increased yield and fiber consistency, and improved uniformity of supply (Jahala et al, 2010).

2.2.2 Market

A reasonable breakdown of the end uses of linen products is as follows: 60% apparel, 15% household textiles, 15% furnishing fabrics, and 10% industrial fabrics and sewing threads (Franck, 2005). An important advantage flax has over other bast and leaf fibers is its capability of spinning relatively fine yarns, which enables a much larger variety of available fabric weights and structures. Another aspect of flax that adds to its advantage over other fibers is the two fiber types that are produced from this plant (long and short fibers called line and tow).

Flax is more expensive than other bast fibers and has a higher cost premium over cotton and polyester, which makes competition higher for flax products. This is because the production of flax fiber is labor intensive, with the added operations of retting, the turning and lifting of the retted stalks, and the field occupation of the retting stalks for several weeks. Another aspect that results in higher cost premiums is the textile machinery developer's reluctance to focus on flax manufacturing machinery, because of the relatively small size of the industry.

Flax can be efficiently processed on dry spinning machinery made for other fibers, such as cotton therefore can be manufactured in many more facilities that are typically used for cotton production. Typically wet spinning, or spinning of fiber in their wet state, is not used on flax fibers because, the capabilities of wet spinning flax have high labor costs, which account for 20% of production costs as compared to 5% or 10% for cotton production (Franck, 2005). Environmentally, flax uses chemical fertilizers and weed and pest control, making it slightly less environmentally friendly than other bast fibers, but it uses significantly lower amounts than other commercial fibers such as cotton. The reason there a measurable decrease in the amount of chemicals is attributed to the fact that, during the field retting process, some of the chemicals are returned to the soil. The retting process decreases the need for additional chemicals for later rotation crops.

In the production of linen products, the other negative environmental effects come from possible use of chemicals containing chloride and dye effluent (Franck, 2005). According to research done by Zahran (2009), efforts have been made to develop increased environmentally friendly methods for full flax bleaching. Due to the push towards a more environmental future for the textile industry, hydrogen peroxide and peracids are increasingly used as substitutes for chlorine-based bleaching agents with elemental chlorine free and totally chlorine-free sequences (Zahran, 2009).

Sodium perborate (SPB) ($NaBO_3.4H_2O$) has been developed for eco-friendly bleaching of cotton. SPB presents advantages of being non-toxic (to plants, animals, and humans), safe, and inexpensive industrial chemical. It is considered a solid form of hydrogen peroxide but provides better stability and convenient, safe handling. It is a self-activating agent, meaning no other catalysts are needed in the bleaching process. After oxygen is released, SPB breaks down into natural borate and water, making it more ecologically conscious. Lastly, it is more economical for water and energy conservation because it de-sizes, scours, and bleaches in a one-bath, one step bleaching process (Zahran, 2009). These methods recently have been tested for the application of eco-friendly flax bleaching. Effects of the pH value on percentage of loss in fabric weight, whiteness index, tensile strength, and carbonyl and carboxyl content were also measured within this experiment (Zahran, 2009). Although there is some loss of strength due to these processes, it is not unusual and is mainly due to the removal of impurities and natural non-starch polysaccharides such as pectin, hemicellulose, and lignin (Zahran, 2009). This research suggests that the move towards more environmental processes in flax bleaching is possible.

Other ecological attributes related to flax include: 1) the growth in the amount of farmable land in temperate climates, 2) the suitability as a rotation crop which decreases the amount of chemicals needed for weed and pest control, 3) biodegradable properties (unlike synthetics), and 4) the decrease in energy consumption during the manufacturing process when compared to other natural fibers and synthetics.

2.2.3 Physical characteristics (from product developers point of view)

Some distinctive physical properties of flax that distinguish it from other fibers are rapid absorption and desorption to moisture, high chrystallinity of the cellulosic component of the fiber which results in high creasability of linen fabrics, low extensibility of flax yarns, low tenacity of fibers and yarns, poor abrasion resistance, high luster (especially fabrics produced from wet-spun yarns), and excellent drape. Tensile strength of flax fibers is twice as high as cotton and three times that of wool. Flax fibers are 70% cellulosic, so they do not provoke allergies and are absorbent to humidity. This allows the skin to breath if the flax is made into apparel products. Linen can absorb up to 20 times its weight before feeling damp, providing a cool and dry fabric for apparel and household bedding. Linen fabric has also been proven to be thermo regulating, and has heat conductivity five times that of wool and nineteen times that of silk. In hot weather linen clothes can help keep people 3-4° C cooler than those wearing silk or cotton and studies show that a person wearing linen perspires 1.5 times less than those wearing cotton and two times less if wearing viscose (Munder, F, et al., 2006). Flax fibers are characterized by higher length to thickness ratio, length to width ratios and lower bulk densities. Flax fiber is soft, lustrous, and flexible.

Similar to hemp, flax can be cultivated for seed, or for textiles, and generally different varieties are used. When mature, fiber flax varieties generally stand about 80 cm- 120 cm in height with a diameter of around 3mm, oil varieties are shorter (60-80cm) and have somewhat thicker stems. In some cases the same variety of flax can be cultivated for the production of both textile products and collection of seeds for oils. Although flax is only moderately susceptible to pests, precautions may need to be taken, as well as protection against weeds is essential. Subsequently, compared to other textile fibers, cultivation and manufacturing requires less weed control chemicals then cotton (Franck, 2005).

Flax yarns are primarily used in woven fabrics (most commonly woven using rapier weaving machines), and less often for knitted fabric. The relatively high flexural rigidity of the flax fiber produces a yarn with high bending stiffness. When machine knitting, the yarn must be able to bend easily in order to form a loop (Franck, 2005). One hundred percent linen knits can be found in outerwear and men's socks. The lined fiber used for these products is wet-spun linen yarns. In order to enhance the properties of the yarns for knitting, an application of wax is needed to increase flexibility and decrease fly. The advantages that these products contain include comfort, lightness, and lustrous appearance. More commonly and more successfully, knitting two way or three way blends with flax can take advantage of the lustrous linen look, without the complications and technical problems associated with knitting 100% flax yarns. Flax fibers are used in many applications, and are known for its properties of being soft, lustrous, flexible, strong, good length and fineness. Flax has a high rate of moisture absorption and desorption and relatively low fiber rigidity, which makes linen fabrics cool and comfortable in warm and humid conditions (Franck, 2005).

2.2.4 Current uses for flax fibers

There are many uses for flax, including linseed/flax edible oil, medicinal, textiles, animal, and industrial products. With the array of products that can be produced from the flax plant, there is little waste created within the manufacturing process, adding to its benefits for the environment (Jhala, 2010). Figure 3 shows a table of the diversified products made from the flax plant.

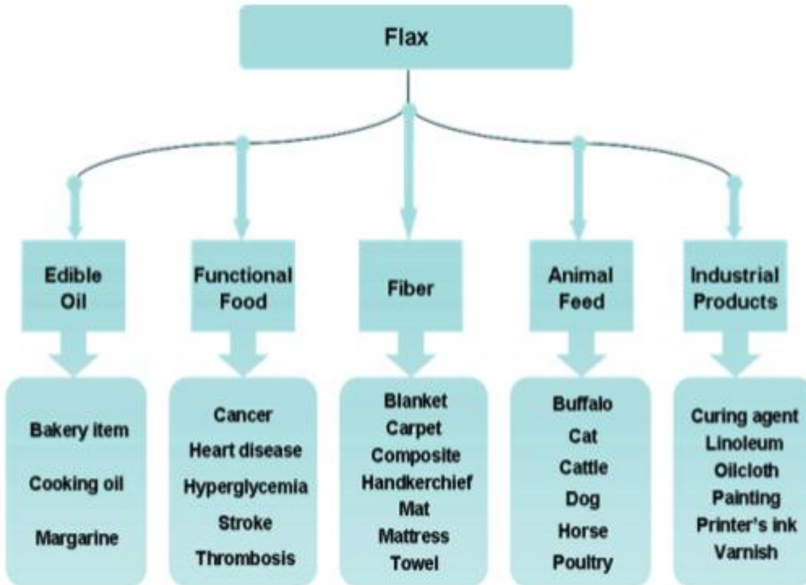

Figure 3: Diversified products of flax
(Image: Jhala et. al, 2010)

As flax is processed, the result is long fibers and short fibers. Long fibers are used in the production of luxury products such as high quality handkerchiefs, bedding, curtains, drapery, cushion covers, wall coverings, towels, other decorative textiles, and materials for suits and dresses. Short fibers traditionally are used for low value products such as blankets, mats, mattresses, and carpets (Jhala, 2010).

The possibility of spinning fine yarns from line flax enables a much larger variety of fabric weight and structure then is possible from any other bast fiber. While the shorter fibers (tow) also add to this variance and provide the ability to produce a wide variety of available fabrics. Other products that have been made from flax include middle to light-weight apparel items made from linen blends such as silk, ramie, cotton and polyester. These linen blends for apparel paved the way for heavier weight linen fabrics for interiors such as the cotton warp, and linen weft fabrics. Linen is used in many household textiles such as tablecloths, serviettes, placemats, sheeting, pillowcases, duvet covers, towels, tea towels, and glass and floor cloths. Linen products could be sold at higher price than cotton because the lustrous appearance, cool hand and drape denote a luxury Product. In the sixteenth century linen was classified as luxury textile alongside of velvet, silk, taffeta, and chiffon. Today, Linen is sold as luxury sheets, claiming linen can actually help you get to sleep faster and make you sleep deeper because of its insulating properties in the winter and cooling properties in the summer. Linen is also known for its low elasticity, which creates a fabric that will retain its shape and functionality over a long period of time without deformation

Flax had been used in some technical fabrics such as agriculture twine, ropes and cordage, and sometimes blended with hackled tow to produce heavy industrial products such as awnings, and post bags. Presently these end uses have been replaced by synthetic fibers, which are lighter and non-water absorbing.

Figures 4 and 5 show examples of diversified, high value added end products made from flax. As displayed below, flax can be made in an array of bright colors and added ornamentation such as embroidery and other decoration techniques can result in a more luxurious and desirable product.

Figure 4: Flax used as high value added products
Image: www.belgianhuis.com

Figure 5: Flax used as high value added bedding
Image: www.bellanottelinens.com

2.2.5 Potential uses of flax fiber

Recent developments have focused on finding an economical method of processing flax as a new trend in the textile industry. Dr. Mehdi Azarschab at the Institute of Textile and Process Engineering in Denkendorf developed a new process. The modern flax technology and yarn processing is done on the R 40 rotor spinning machine, which operates with efficiency of more than 97%. This processing and technology produces linen with improved characteristics such as higher elongation, lower hairiness, lower shive and trash content, significantly better downstream processing (weaving efficiency up to 95%), and lower manufacturing cost. The process of extracting the fibers has no adverse ecological effects because virtually no chemicals are used in the process, which makes it more environmentally attractive fiber as well. The improved quality of the fabrics from these new developments include better abrasion resistance, higher dye receptivity, lower finishing cost, more pleasant wearing behavior, and reduced tendency to crease. New developments in the processing of bast fibers coupled with an increased interest in consumers for natural fibers, may prove to be very beneficial as oil and cotton prices rise. (Thielemann, A., 2010). Some recent experiments with processing flax fiber involve Spray Enzymatic Retting, Steam explosion, or chemical retting. All of these methods are being researched to replace traditional retting methods because of the disadvantages associated with dew retting, and water retting. Spray enzymatic retting is a method for processing flax fibers for enhanced fiber properties. This method uses a pectin-rich enzymatic formula to soak flax stems, at high humidity for a result in uniformity of fibers and some improved properties. This method has not yet been commercialized because cost is a major obstacle in commercial development (Akin, et. al. 2000).

2.3 Jute

2.3.1 History/ Development

Jute, which is mainly grown in south-East Asian countries such as India, Bangladesh, China, Myanmar, Nepal and Thailand, is primarily used for the packaging of grains, sugar, cocoa, coffee, other food crops, as well as for cement, fertilizers, salt, and cotton. India and Bangladesh are the primary jute fiber producers of the world, accounting for 93% of production (Franck, 2005). The jute plant has many species (over 40), only two of which are commercially cultivated. These are known as 'White jute' and 'Tossa' jute.

In the 1980's after the growth in popularity of synthetics, the steady decline in the traditional jute industry began. This decline forced the government and participants in the jute industry to create programs for the development of diversified jute products in order to revive the jute economy and to improve the economic conditions of jute farmers and workers in producing countries. To stimulate the industry, research and development efforts worked to create high value added products with this versatile and environmentally friendly, natural fiber. New technologies were used to create products that went beyond the traditional jute products such as packaging materials, ropes/twines, and carpet backing. Jute was used to create innovative products such as interior home textiles, jute geo textiles, jute composites, technical textiles, fashion accessories, and other diversified jute products (www.jute.org, 2011).

2.3.2 Market

Franck (2005) believes that soft luggage products made from jute have high potential for marketability, as well as in the areas of high fashion handbags, and re-useable grocery bags. Jute is also used in the field of civil engineering as a geo-textile. Geo-textiles are used for separation, filtration, reinforcement, drainage, and protection/erosion control. Jute has replaced many synthetics in this field in cases where durability is not a concern, such as soil erosion and slope protection (Franck, 2005). Jute is one of the least expensive textile fibers, so could potentially be cost effective in the use of blended fabrics, with a fiber that possesses softer hand and drape characteristics to even out the stiffness of jute yarns (Azad K.A., 2009). Depending on the demand, price, and climate, the annual production of jute and other allied fibers is around 3 million tons (www.jute.org 3/1/11). The bulk of the manufactured fabrics is most commonly used for packaging and backing, and is called burlap fabric. Burlap has recently been making its way back into the interior market in the form of upholstery fabrics, carpets, and wall coverings. Whether recycled feed sacks are being re-purposed as a rustic take in interior designs, or new burlap fabric is used for a cleaner, more streamline look, you can find this material starting to make a comeback in the high value textile industry.

2.3.3 Physical characteristic (from a product developers point of view)

Jute is a strong fiber, which can be spun into yarn. The fiber characteristics, however, include low extensibility, brittle fracture, and small extension at break, which creates fabrics that are stiff and non-stretchy. This makes jute a better fiber for commercial packaging products, and other technical textiles. Commercially, jute is not used for consumer textile fabrics because of the limitations it has in regard to feel, stiffness, drape, coarseness, and low abrasion resistance. With regard to its low price, it is necessary to find alternative uses for jute fibers for relating the economic viability of the jute industry and therefore supporting those who make their living by it (Azad, 2009).

Jute is still often used as a material for carpet backing, carpet yarn, cordage, as well as felts and padding, decorative fabrics and other industrial uses. Some suitable jute products are canvas cloth and tarpaulins, jute laminates, jute and jute blend fabrics, soil savers, curtains made from jute blends, jute wall coverings and dividers, nonwoven's for use in automotive industries (composites), jute blends for sound and heat insulation, flame proof and mildew proof fabrics with jute yarn used as core combined with high performance fibers as sheath. Jute has previously entered the market as decorative fabrics, and wall coverings, but has since been replaced because of some technical characteristics of the material, including color fastness and low quality (Franck, 2008). With the low price of jute, it may be a viable option to start making into more commercial, eco-friendly design products, for a better financial return.

2.3.4 Current uses of jute fiber

Burlap is gaining in popularity for home interiors because the natural color and rough texture fit in well with a 'rustic home' look. This is a significant trend of 2011/2012 interior markets (Unpublished report in the holding of a private company, September, 2010. Emily Boyle J.S. Royal Home). This can be used as an inexpensive way to add texture, and depth to any room design weather the theme is rustic, bohemian, or eclectic, to more traditional. Burlap can be used as curtains, inexpensive upholstery fabrics, wall coverings and accessories. Figures 7 and 8 demonstrate some current uses of juts as high value added products that are in the industry today. Figure 6 demonstrates how vintage sacks can be up-cycled to create rustic interiors, While Figure 7, is a new fabric called WOJO^{tm} that uses recycled Starbucks jute coffee sacks and combines them with wool to create this innovative new textile that will be used in the seating of Starbucks coffee shops internationally (Hussey, 2011).

Figure 6: Jute Used as High Value Added Interior Product
Image: Hudson Home Goods

Figure 7: WOJO™ fabric created with recycled jute and pure New Zealand Wool
Image: www.Theformary.com

2.3.5 Potential uses of jute fiber

For jute manufacturing to continue to be prevalent in the future, developments must be made to improve the fine-quality of jute fibers (Franck, 2005). If jute is to have a long-term future, it will be essential to find new outlets for jute products. Jute is heavy weight and is steadily being replaced by more lightweight materials. To continue its lifespan, new strands of jute yarns must be created that will result in lower linear density of the yarns. Presently jute yarns have a linear density ranging from 15.0-30.0 denier. Research has been done in order to improve the quality of jute fibers with enzymes and through the classical method of plant breeding, which has improved hand (softness) and decrease linear density and weight-loss. The use of enzymes also results in lower moisture regain, abrasion resistance, and tensile strength.

Environmentally, jute is biodegradable and a natural resource. Jute does not generate pollution during agriculture cultivation, or after use, as jute disposal does not cause environmental hazards (Franck, 2005). Bags and sacks produced using jute are reusable, which makes them more environmentally friendly than disposable packaging as well as less expensive in the long run. Energy consummation is lower in the cultivation and conversion into jute products then many other textile products, predominantly cotton and synthetics (Franck, 2005). Growing one ton of jute fiber requires less than 10% of the energy used for the production of one ton of synthetic fibers (IJSG, 2003). Jute is an annually renewable energy source with a high biomass production per unit land area (jute.org, 2011). Like hemp, cultivation of jute plants increase soil fertility, provide substantial amounts of nutrients in the form of organic matter and micronutrients, and acts as a barrier to pests and diseases for other crops planted in rotation with jute. Jute also has high carbon dioxide (CO_2) assimilation rate and it cleans the air by consuming large amounts of CO_2, which is the main cause of the greenhouse effect. Studies show that one hector of jute plants can consume about 15 tons of CO_2 from the atmosphere and release about 11 tons of oxygen during the growing season (approximately 100 days) (IJSG, 2010). Jute life cycle impact on the environment is lesser than Polypropylene (PP) all life cycle stage impacts. 1 metric tons (MT) of PP releases 7 MT of carbon dioxide (CO2) in the nature whereas 1 MT of Jute fiber removes 2 MT of CO2 from nature. Jute and jute products are also photodegradable, thermal degradable, non-toxic, and have UV absorbing capacity. In

Figure 8, the greenhouse gas emissions have been benchmarked using bags as the product.

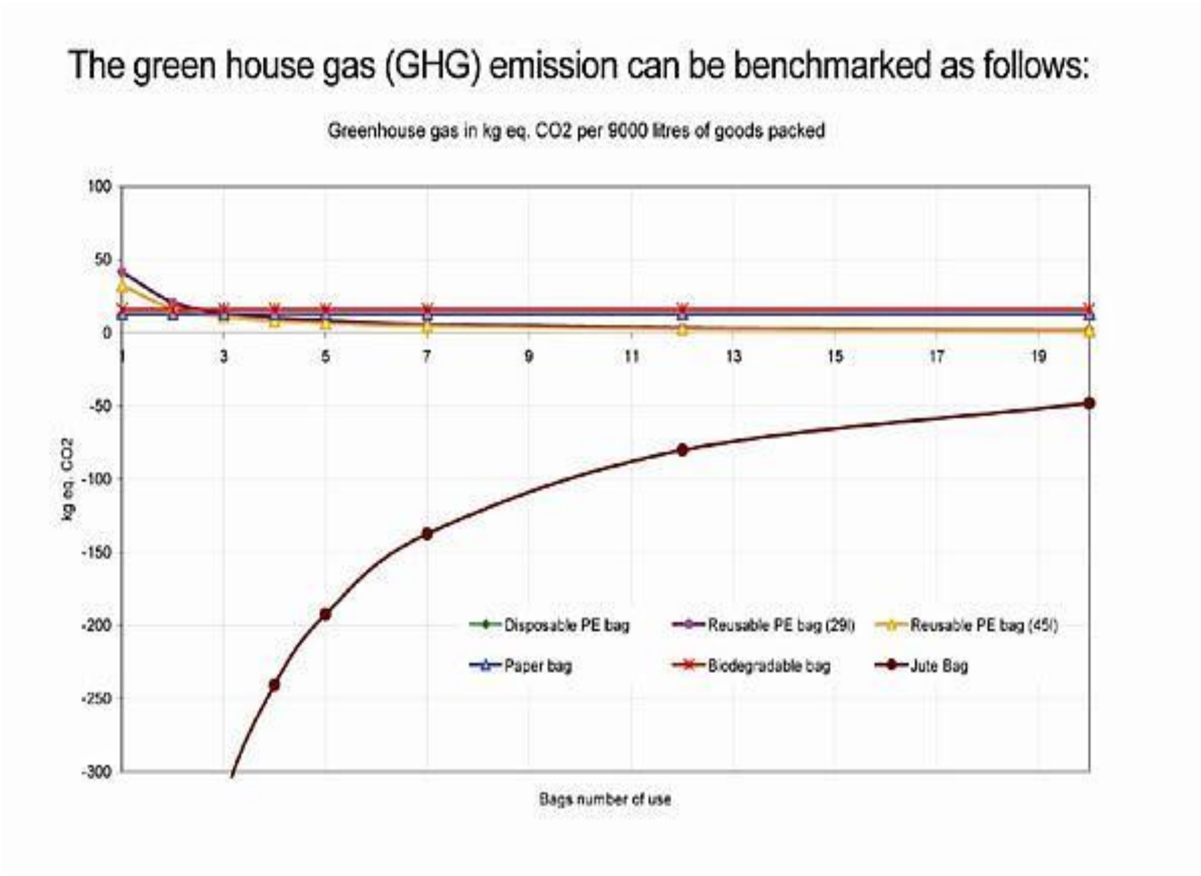

Figure 8: Benchmarking greenhouse gas emissions of different products
Image: International Jute Study Group, 2010.

With these environmental properties, and low price, jute blend fabrics have the potential to create a considerable demand. In a 2009 study by Azad, K.A, and Jafrin, S., cotton- jute blends have the potential of becoming an alternative to 100% cotton fabric. They determined that with the use of sizing material, the tensile strength of cotton-jute blends increases and the hairiness decreases. The result of the sized union fabric was equally as smooth and durable compared to 100% cotton fabrics and considerably more cost effective, therefore increasing the use of jute is possible through diversified product creation (Azad, K. A., 2009). The steady decline in market for traditional jute products has forced government and jute industry to take up programs for diversified jute products. Research and development efforts have been supported in efforts to develop this versatile and environmentally friendly fiber. The conventional products from jute are ropes, twines, and carpet backing, but technologies are evolving to increase the market of new jute products such as home textiles, jute composites, jute geo-textiles, paper pulp, technical textiles, chemical products, handicrafts, fashion accessories and apparel. Figure 9 demonstrates the potential that bast fibers, such as jute, possess to create a collection of diversified products.

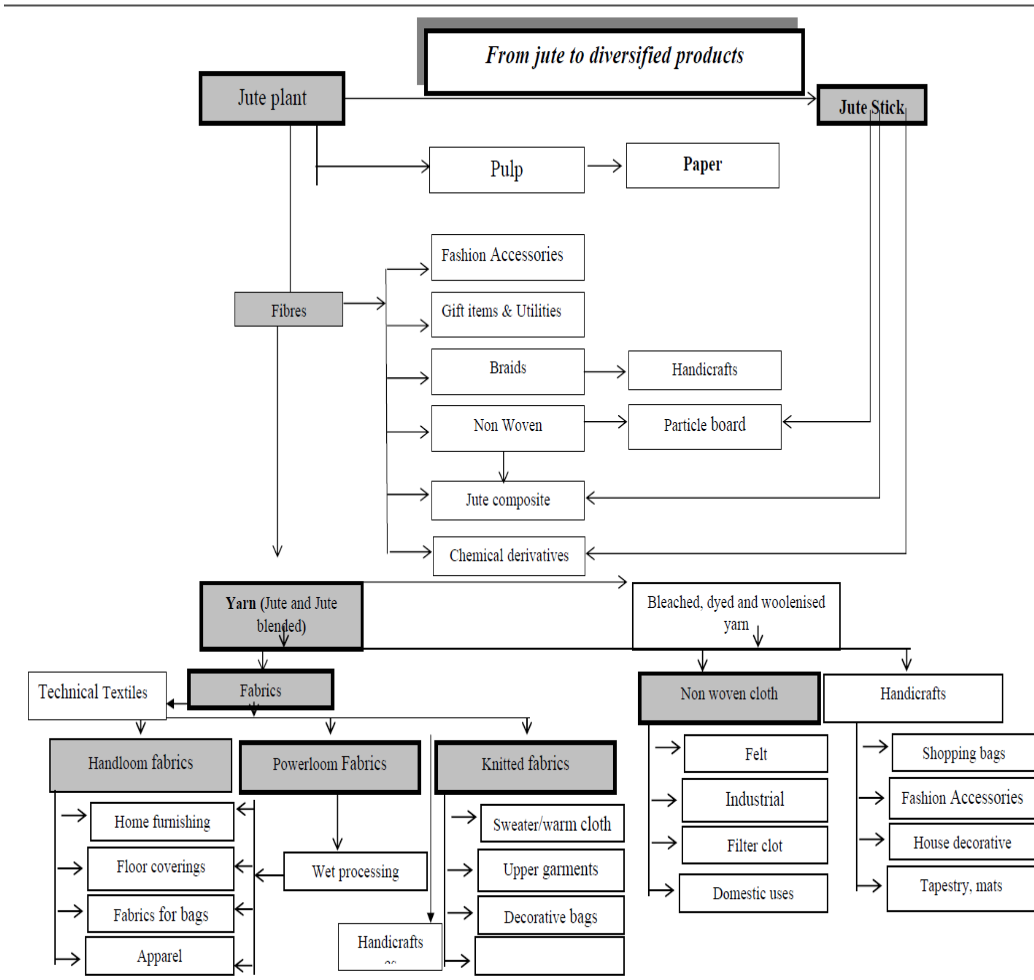

Figure 9: Diversified products from jute
Note: From www.jute.org

2.4 Hemp

2.4.1 History/Development

Hemp was traditionally used as raw material for industrial purposes because of its high strength (Svennerstedt, 2009). The fiber was originally cultivated in Hungary as a woven fabric used to make harder wearing, stronger fabrics than other commercial fibers. Hemp also served as a raw material to make rope, twine, bags, tarpaulins etc.

(Franck, 2005). From the sixteenth to the eighteenth centuries worn out hemp products were recycled and used as raw material in paper mills (Van der Werf, 1996). Hemp, with its ability to be cultivated in many climates, soon spread throughout Europe as a textile crop. The fiber was most abundantly used in the 1700's and became popular again in World War II for war uniforms, because of its durable and antibacterial properties. During the 1960's competition from synthetics became too strong and the hemp processing again became scarce. During the 1960's hemp became associated specifically with recreational drug use, due to the THC that is found within marijuana, and was banned (Svennerstedt, 2009). This type of hemp is unlike the kind for seed and fiber, which has absolutely no way of being used as a recreational drug (Hemp Industries Association, 2009).

The hemp plant has many varieties of species, but two forms of hemp have developed under climatic conditions, northern and southern hemp types (Franck, 2005). The northern type of hemp is better in the cultivation of hemp for seeds as the yield is higher, while southern type is taller; more branched and has higher fiber yield (Bengtsson, 2009). Hemp is mainly bred in Europe currently, and breeding has been done in order to increase fiber yield. The breeding of hemp for greater fiber yield began in the 1920's, when the hemp plan was still of popular demand (Bengtsson, 2009). In 1996, France developed breeds of hemp that were nearly void of THC and therefore can be used to contradict the negative connections to the use of hemp as a drug (Bengtsson, 2009). When planting the hemp seeds for fiber it is important to use a high seeding rate. Most countries use a seeding rate of 100-140 kg of seed per hectare that initially produces 500-700 plants per square meter. The high seeding rate increases plant mortality, but closer spacing produces stalks with smaller diameter and high fiber content. The fibers are directly related to their stalk thickness and height. While taller thinner stalks create thinner fibers, which are more appropriate for textiles. This is why it is important to grow the plants closely together. Seed strain also contributes to the thickness/thinness of the fiber. Hemp matures in 80-150 days for fiber harvesting depending upon the variety and location. Most hemp varieties mature in 120 days. Early harvesting of hemp will result in lower yields of weaker fiber, while delayed harvesting will result in stems that are difficult to ret and yield coarse, harsh fiber with little luster. This makes it very important to harvest at the proper time to secure the highest quality fiber (L. Serbin, personal communication, 2012).

2.4.2 Market

In the European market, alternative fiber crops such as hemp and flax are increasingly interesting to farmers because the plants grow well in a variety of different temperatures in Europe. In contrast, cotton can only be grown in the most southern areas of the continent (Turunen, L. et al., 2006). In the last few decades, revived interest in hemp as a renewable resource has developed. Hemp can supply high fiber yields, requires little to no pesticide use and suppresses weeds and some soil borne diseases, and therefore hemp fits into organic/sustainable farming systems (Van der Werf, et al., 1996). Hemp fibers, once degummed, can vary in length from ½ inch to the length of the stalk (168 inches). In the processing stages, these longer fibers are cut down to 4-6 inches. These longer fibers are then used to make 100% hemp yarns, using spinning machines that were made originally for flax fibers and were slightly modified for hemp production. These pure hemp textiles use long hemp fibers to create strong fabric with smooth, lustrous surface. The shorter fibers (½ -2 inches) are usually blended with cotton to be spun on conventional cotton spinning machinery. Any combination of hemp and cotton can be spun together from 5%- 95% hemp depending upon the ratio and properties desired. Hemp ads some stability and strength to cotton, making the fabric stronger while lowering shrinkage. Hemp has also been blended with other natural fibers such as wool, silk, and flax, as well as synthetics or extruded fibers such as bamboo, tencell, nylon, rayon and polyester. Hemp adds strength, absorbency, and breathability to these fabrics, while the other fibers add stability, flexibility, and smoothness to the hemp (L. Serbin, personal communication, 2012).

Because the hemp industry is only recently becoming a new potential market for the textile industry, the processing techniques are outdated, and expensive to run. In order to minimize costs and lower the amount of skilled workers needed, traditional flax breaking machinery is sometimes used. However, this type of processing causes all of the fiber to be broken down into tow, making the fiber appropriate for lower value end uses, such as paper and pulp (USDA, 2000). Currently, about four billion tons of hemp, flax, jute and kenaf are grown globally, representing vast sustainable and renewable resources for product development that would have lower impact on the environment than many other fiber sources (Cockcroft, 2001). Presently the industry is taking advantage of hemp's tensile strength properties and using them for environmental composites for the automotive industry. The benefits of these environmental composites include cheaper price, less environmental impact, less prone to splintering, and save weight by as much as 30%, which improves fuel consumption of the automobile (Cockcroft, 2001). If this industry adopted the use of these natural renewable materials for their production, farmers would benefit from cultivation of these crops for this and other soft, high value added textile products.

2.4.3 Physical characteristics (from product developers point of view)

Hemp is closely related to the flax plant, both producing similar fibers from their bark. As a fiber however, hemp has many attributes that differentiate it from other closely related bast fibers. These differences extend into the character of the yarn and ultimately the fabrics they produce. Hemp fibers are said to be one of the strongest natural fibers, with high tensile strength, and low elongation. Hemp characteristics such as breaking strength is slightly higher than that of flax, its elongation is low, ranging around 2-3%, and its flexibility depends on the fineness of the bundle (Franck, 2005). With hemps low elongation rate, it has the ability to retain its shape. This makes hemp perfect for interior/upholstery fabrics because it has the ability to be pulled taught, and remain firm throughout the life of the furniture (L. Serbin, personal communication, 2012) In its natural state, hemp is coarser and thicker then flax, although with processing, these characteristics can minimize these differences (Lin, 2005). Hemp fabrics are comfortable because of an eight percent absorption rate, and are easy to care for (machine washable), because of their percentage of cellulosic material

(78%)(Lin, 2005). Hemp also has the best ratio of heat capacity compared to flax and cotton, giving it superior insulation properties. This means hemp keeps cooler in warm weather and warm in cold weather (L. Serbin, personal communication, 2012). Many of the properties that are unique to hemp are because of the porous nature of the fiber. Under the microscope, hemp does not look like a flat rod, but rather is filled with holes and notches. Hemp has a greater surface area and is more water absorbent. This increased surface area allows fiber to dye well and retain color. The porous nature of the fiber allows hemp to breathe. The air that is trapped in these holes is warmed from the body therefore making hemp garments naturally warmer in cold weather. This air flow hinders the growth of bacteria as well, making it naturally antimicrobial (L. Serbin, personal communication, 2012). Hemp has many advantages over other crops, especially as an alternative to cotton, which uses vast amounts of irrigation water and agrochemicals. Hemp can also be a substitute for wood fibers (such as rayon), and are substantially more eco sensitive. Hemp is a durable rotation crop, improves soil fertility and can survive in many climates (Lin, 2005). The hemp plant has a deep root system, which aerates and improves the soil structure (Bengtsson, 2009). Hemp cultivation also required little or no pesticide and herbicide use (Lin, 2005). As a rotational crop, hemp serves as an absorbent to pollutants in the soil, such as heavy metals. The entire hemp crop can be put to use, as the stalk is used as fiber, the leaves and hurds can be ploughed back into the soil as fertilizer, or made into products such as animal litter, which can then be used as fertilizer. Hurds can also be used in the manufacturing of paper goods, or particleboard for the use of furniture building. Essentially no part of the plant is wasted. On the negative side, hemp processing isn't as environmentally friendly as more modern fibers. If water retting, is used, large amounts of clean water is used, and polluted, which takes energy to clean, as well as conduces large amounts of water usage (Franck, 2005).

2.4.4 Current uses for hemp fibers

Industrial hemp can be grown for many end uses including seeds for food and oil, fiber for textiles and insulation, reinforcement in composites, paper, particleboard for the use of building materials and furniture, and alternative fuel (Bengtsson, 2009). Although Hemp has many end uses, when a farmer decides to grow hemp, they must choose if they will be growing hemp for fiber or for seed. At the farm level, these are the only two choices; all other products are made from further processing of the raw material (L. Serbin, personal communication, 2012). The most valuable raw material to grow from industrial hemp is the fiber. On average, hemp fiber can be sold from the farm at approximately $0.55 to $0.80 per pound, whereas the seed only gets $0.39-$0.60 per pound (L. Serbin, Personal Communication, 2012). The hemp fiber has the most uses and therefore has the most value to farmers. More recently, Hemp has begun to rise in the market as an environmentally friendly alternative to interiors and apparel (Kadolph and Langford, 1998). Hemp textiles can vary from jersey knits to terrycloth, to brocades, and be blended with everything from Tencell® to cotton. Hemp fiber offers great properties for textile products such as high durability and breathability compared to cotton. Hemp based textiles on the market today include apparel and accessories, such as T-shirts, pants, dresses, baby clothes, bathrobes, and shoes; housewares such as blankets, shower curtains, and rugs, and sundries such as hammocks and pet supplies (Rothenburg, 2001). Hemp has been used in Europe as a sustainable building material, and more recently this has been adapted in North America. Because of hemps natural properties, the houses built using *hempcrete* are naturally non-toxic, mildew-resistant, pest free, and flame resistant. The homes are more energy efficient and healthier for the inhabitants (Koch, 2010). Figure 10 shows a 3,000 square foot home with thick hemp walls that was completed in the summer of 2010 in Asheville NC.

Figure 10: Environmental Hemp home; Asheville North Carolina
Photo: Peak Definition, USA Today

2.4.5 Potential uses of hemp fiber

As a plant that can be easily incorporated into cropping systems, hemp is an excellent crop to integrate into a growing rotation with winter wheat. Hemp is considered an admirable break crop, which is a secondary crop in sustainable agriculture that provides a "break" from the cycle of weeds, pests, and disease. Hemp is highly effective at suppressing weeds because of its thick and close growth, and therefore reduces costs for herbicides for the following crop. Hemp also replenishes the soil of the nutrients that are leached from growing other crops, and is has been reported that a significant increase in wheat yield grown after hemp occurs compared to monoculture wheat (Turunen, L., et al., 2006). There has been increased hemp cultivation in Europe, but the numbers are still modest. Some of the industries for this fiber include specialty papers (for smoking), technical textiles (twine, rope, and geotextiles), car parts (composites for dashboards etc.) and building materials (insulation materials). However, with the high labor costs of the European union, hemp production can only be profitable if the material can be transformed into high value added end products, such as high quality textiles (specifically for apparel and interiors) (Turunen, L., et al., 2006). The interest of using hemp is growing exponentially, which will help to bring attention to improving the processing. This is a slow process due to the availability to grow hemp in certain countries such as North America. Many companies are adopting hemp as a sustainable blending fiber in apparel products and home interior products.

2.5 Ramie

2.5.1 History/Development

Ramie production mainly originated in China, Indonesia, and India and it was also cultivated in the Congo and Algiers. Harvesting of Ramie is difficult because of the unevenness of the strands and the need for physical labor of pounding and scraping for separation of fibers. Ramie production is not widely used because of the lack of production technologies mechanized for ramie manufacturing (Franck, 2005). The ramie crop is a close relative to the stinging nettle plant, but does not possess the stinging hairs. The plant is relatively easy to cultivate, and prefers rich, warm, sandy soils, typically in high temperatures and high humidity. It is important to have relatively evenly distributed weather and rainfall when cultivating ramie, because sudden changes result in irregularities in the fiber. Ramie is a perennial crop, lasting 6-20 years, it is susceptible to pests and disease, and needs room to grow (as to not overcrowd roots). Ramie can be harvested up to six times a year in perfect growing conditions, but 2-4 times is more accurate (Franck, 2005).

Leading producers of ramie in the current market include China, Taiwan, Korea, the Philippines, and Brazil. The usage of ramie hit its peak in the 1980's with the popular surge of using natural fibers and also due to a loophole in the import regulations of the Multi-fiber Agreement (MFA).

2.5.2 Market

Originally, the fashion market didn't see ramie as a contender until the surge of the mid 1980's. Ramie in the ready-to-wear market is now increasing slowly and ramie is often found in cotton blends for woven and knitted fabrics that can vary from fine linens to course canvas like fabrics. Ramie has been considered as an economical alternative to flax because of its structural and aesthetic similarities to flax and its lower price. Because of its harsh hand and poor resiliency of 100% ramie products, it is most commonly used as a blend with other fibers such as cotton. This provides a cheaper material and contributes some of the characteristics of linen, although the colorfastness and dyeability is less than that of linen and substantially less than that of cotton (Cheek, 1990). Typically Ramie is blended in a 55% ramie/ 45% cotton blend, which gives the uneven appearance of linen, although the luster is lost. Ramie is extremely absorbent, and has natural resistance to bacteria and mildew as well as holds up well to washing and high temperatures. This fiber has a small market share and will only grow if substantial developments in the processing procedures are improved (Franck, 2005). Ramie is used in non-textile applications such as paper pulp for high quality papers such as bank notes and cigarette papers. Ramie is also used in many medicinal applications (Franck, 2005).

2.5.3 Physical characteristics (from product developers point of view)

Ramie possesses good properties such as absorbent, quick-drying, strong, and resistant to mildew and has a lower price tag when compared to flax. It is often used as a flax substitute for linen-like fabrics that are less expensive. It could also be used in blended cotton/ramie applications for a linen-like effect (Baugh, 2008). Ramie fiber is very fine and silk like, naturally white in color and has high luster therefore can create fabrics with high quality and premium valued properties. Ramie fibers are slightly stiffer then flax fibers because they are more crystalline. Table 2 shows a comparison of properties of flax, ramie and cotton.

Table 2: Properties of selected natural cellulosic fibers

Fiber	Cotton	Flax	Ramie
Tenacity (g/d) Dry Wet	 3.0-5.0 3.3-6.0	 2.6-7.7 3.1-9.2	 5.3-7.4 5.8-8.9
Elasticity recovery, 2% elongation (%)	75	65	58
Density (g/cm^3)	1.54-1.56	1.5	1.56
Moisture Regain (%)	8.5-10.3	12.0	7.8

Source: Hudson, P. B., Clapp, A. C., & Kness, D., 1993

2.5.4 Current uses for ramie fiber

Ramie is most often found in blends of 55% ramie/45% cotton, which retains the uneven linen like texture, but loses the luster of the ramie. When synthetics are included in the blend, wrinkle and shrinking resistance can be improved. When blended with wool, shrinkage is greatly reduced. The advantages of cultivating and using ramie include physical properties such as 1) resistance to bacteria, mildew, and insect attack, 2) extremely absorbent, and dyes fairly easily, 3) an increase in strength when wet, 4) a smooth lustrous appearance that improves with washing, and 5) shape retention and low shrinkage. Disadvantages include; low elasticity, low resiliency, low abrasion resistance, wrinkles easily, and the fact that the fiber can be very stiff and brittle.

Although ramie is considered as a high quality fiber, its production is labor intensive and because of lack of manufacturing innovations, it is unlikely to be economically feasible under current conditions. Ramie is not under research and development in well-equipped or more developed countries therefore the growth in popularity of this fiber is at a standstill, although with current research on other bast fiber processing growing, this fiber could become a potential competitive fiber for traditional growing areas (Franck, 2005).

2.5.5 Potential uses of ramie fiber

As stated in the information above, developments on ramie are mostly at a standstill. It will continue to be grown for paper pulp, feed, and for blended textiles. As further processing developments are made to process bast fibers in general, this could trigger potential increase of use of ramie (Franck, 2005).

2.6 Kenaf

2.6.1 History/ Development

Traditionally, like other bast fibers, kenaf has been used for products such as rope, twine, and burlap type fabrics for sacks. Kenaf was first used in Northern Africa, and India has now used and produced kenaf for over 200 years. In the United States, Kenaf research began during World War II for supply of cordage material for the war effort (Webber et. al, 2002). During this time, kenaf was determined as a suitable crop for US production, resulting in development for kenaf harvesting machinery, high yield cultivars, and cultural practices that helped increase kenaf production (Webber et. al., 2002). The processing procedures of kenaf continue to be evaluated. The harvest method depends on the production location, the equipment availability, processing method, and final product use.

2.6.2 Market

Kenaf has mostly been used as a blending fiber with cotton for textiles use. Kenaf has also been use in geo-textiles to create nonwoven textiles and insulation materials. Kenaf can be used for fashion apparel, but its properties are not ideal for this type of fabric without further treatments. In a study conducted by Bel-Berger, Von Hoven, Ramaswany, Kimmel and Boylston (1999), kenaf fibers were produced using different retting techniques, blended with cotton and evaluated on their hand. The retting techniques that were used were mechanical, chemical, and bacterial. The results were that mechanically retted kenaf was too stiff to be blended with cotton and cannot be made into good yarns. Fibers processed chemically and bacterially were blended with cotton and made into fabrics to be evaluated on their sensory perception. The results of this study determined that with the use of chemical retting and softeners, the blended kenaf and cotton fabrics were aesthetically pleasing (with the look similar to that of linen), but that without the chemicals and finishes, they were too scratchy for apparel products (Bel-Berger et al., 1999).

This study shows that this potential, inexpensive fiber could be used in blended fabrics, but with the use of the chemicals and treatments, the price is comparable with other possible natural fibers and the sustainability factor diminishes exponentially.

2.6.3 Physical characteristics (from product developers point of view)

To incorporate kenaf fibers into textiles, it is important to establish uniformity of fibers extracted from base to tip of the plant (Ramaswamy et al., 1995). Ramaswamy et al.'s (1995) research discussed a chemical process that is used to extract kenaf fibers for use in woven textile products. Fiber uniformity among kenaf fibers is lacking as well as the ability to use the chemical process in order to produce pliable yarns. In this study, chemical enzymes were used and tested in order to break down the fibers, and test them for strength, elongation, crystallite, breaking tenacity, fineness, gum content, and bending rigidity. These tests using NaOH and HCl are not sustainable and include high amounts of water consumption therefore were not conducive to the sustainability aspect of bast fibers. These tests were important for determining the gum content and biodegradability of kenaf. Therefore gum content must be monitored depending on end product of the kenaf. For woven goods, the gum content must be kept as minimum as possible, however if the end product is nonwoven, a certain amount of gum is necessary for the biodegradable aspect of the product (Ramaswamy et al., 1995).

2.6.4 Current uses for kenaf fibers

The domestic demand for kenaf is currently limited. Most kenaf farmers are contract growing, and therefore there will not be much growth in this area until there is a demand in the market. Kenaf must also be grown close to a processing plant, because the harvested stalks are bulky and heavy. Kenaf is being processed for paper products, as an alternative to wood processing. Rymsza (1998) president and founder of KP Products Inc. presented a case on creating a high value market for kenaf paper at the

First Annual Conference of the Kenaf Association. KP Products is the first U.S. company to commercially produce uncoated offset printing paper made from 100% kenaf fibers and processed totally chlorine free. Although at this stage in processing, the kenaf paper doesn't compare to wood pulp as far as price, Rymsza (1998) says that this is only a result of the small scale of production that is capable at this time. Based on experience to date, confidence is high that a full scale processing capability of kenaf paper product would be competitive and even advantaged price-wise when compared to wood based papers. This product would then have environmental and economic advantages.

2.6.5 Potential uses of kenaf fiber

With the development of synthetic fibers, natural fibers had a downfall of interests for the use in composites, but with the resurgence of the sustainable industry and the knowledge of the benefits of using natural fibers, there has been a reappearance of natural fiber blends as a material for the automotive industry, specifically wood and bast fibers. Most of the flax fibers are the shorter staple fibers, which is a by-product of the textile industry. With this newfound popularity, Europe is making investments to find new and better harvesting and fiber separation technologies for bast fibers, such as flax, hemp and kenaf, which could carry over into the use of these fibers for other end products (Clemons & Caulfield, 2005). Projects such as HEMP SYS, which aims to raise the hemp fiber processing industry as well as research among the Institute of Natural Fibers in Poland, bast fibers are on a potential significantly raising path.

2.7 Tobacco

2.7.1 History/Development

Tobacco does not have a history of being used as a textile fiber. Its history lies in smoking products and some medicinal practices. Only recently has it begun to be looked at for other uses including the possibility of extruding the core stem fibers as potential textile fibers. This is because the chemical makeup of the plant is similar to bast fibers.

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2.7.2 Market

Each year 6.7 million tons of tobacco is produced, and United States produces 4.6% of that tobacco which is among the top 5 producers of tobacco in the world (US census Bureau, 2005). All of this tobacco is produced for the manufacturing and consumption of cigarettes, and only the leaves are used. Research found in United States Patent 3750679 shows progress being made in the processing of the waste particles in tobacco by breaking down the bigger waste particles and reusing them in the manufacturing of cigarettes, but cigarette production results in a large amount of waste of the tobacco plant.

2.7.3 Physical characteristics (from product developers point of view)

In 2011, attempts began to make tobacco into a fiber at North Carolina State University in the College of Textiles. These fibers are located in the core of the tobacco stalk similar to that of other bast fibers. The process of getting the fibers are similar to that of other bast fibers, but has not been attempted at full size production. The fibers must be separated from the rest of the stalk using a microbial process that breaks the chemical bonds between the bast fibers and the woody core; also known as retting (USDA, 2000). Retting can occur by two distinctly different commercial processes; *water retting*, or *dew retting*, also referred to as field retting (Jhala, 2010) A series of retting (Chemical, or biological) have been used in the preliminary samples to receive Tobacco fibers for testing.

After the fibers were obtained, they were conditioned for testing in the physical testing laboratory, in the standard conditions of 70 degrees F, and 65% humidity. During the initial testing of this fiber, complications in retrieving single fibers proved to be difficult because of the natural lignin in the fibers. This caused them to clump together and be easily broken when pulled apart.

The fibers were divided into four groups for testing, these included;

1. fine fibers obtained from hand combing (use estimated denier value of 7.4)
2. Finer fibers pulled by hand (estimated denier 12.6)
3. Coarse fibers from grass like sample (estimated denier 20.8)
4. Fibers pulled from outside of bark (estimated denier 10)

These fiber groups were then tested for their tensile summary, Table 3 shows the mean values of the tensile summary with standard deviations in parentheses. These are only estimates, as this fiber is still in the very beginning stages of testing.

Table 3: Tensile summary of tobacco samples

Sample	# of specimens	Est. Avg. Denier	Peak Load (g)	% strain @ peak Load	Modulus (g/denier)	Tenacity (g/denier)
1	10	7.4	55.1 (26.8)	4.72 (2.80)	258 (182)	7.45 (3.62)
2	9	12.6	74.6 (21.7)	4.38 (2.01)	211 (101)	5.92 (1.72)
3	8	20.8	45.4 (26.1)	1.50 (0.58)	212 (96)	2.18 (1.25)
4	2	10	39.5 (10.8)	3.51 (3.12)	226 (100)	3.95 (1.08)

Note: mean values with std. deviation in parentheses
Source: Krauss, J, Watson, J, Ballard, J. Physical testing Laboratory, North Carolina State University. Personal Contact.

2.7.4 Current uses for tobacco fiber

The current uses for tobacco vary from, most popularly, cigarettes, pipes, cigars, chewing tobacco and snuff. The plant is also used to obtain nicotine sulfate for insecticides and nicotine tartare, which is used medicinally (Borio, 2000).

2.7.5 Potential uses of fiber

Research at the College of Textiles at North Carolina State University is looking into the possibility if using tobacco stems for fiber. Potential uses also involve eco-friendly dye, and potentially using the oils from the plants as toiletries products such as perfumes, lotions, soaps etc. This could be a potentially cradle to cradle product as it would use current waste products to create high value end products.

2.8 Sustainability and product development in the textile industry

The recent focus and awareness on global climate change, water supply and the use of alternative energy, has led consumers to be aware of consumption patterns on the products that are present in everyday life. This leads to the interest of how these products are being produced, and what alternative products are made using more sustainable methods. This recent interest in more sustainable fibers is shown through the worldwide trade with organically grown crops, which has been on a steady rise of about 15% annually. Even the production of cotton is causing major environmental damage because of the large amount of pesticides, fertilizers and defoliants that are used in growing cotton. In 1999, cotton was the second most heavily pesticide-sprayed crop (behind only corn); with approximately 81 million pounds of pesticides applied to upland cotton in the US (Gam, 2007).

This shift towards a more sustainable future of textiles leads to the urgency to find alternative fibers and fabrics for cotton are increasing as vast amounts of agrochemicals and water irrigation is required for the cultivation of cotton (Bengtsson, 2009). The interest of textile production of hemp and flax is promising because they grow well in many different conditions, Europe wide, while cotton thrives only on the southernmost edge of the continent (Van der Werf et. all, 2007). The Properties of bast fibers like flax and hemp have growth potential to become high functioning and high performance fibers. In order to develop these fibers into successful competitors among the already prevalent natural fibers (such as cotton) three aspects must be acknowledged. *Product quality* must continuously be refined; there is a deficiency of pure, fine, homogenous natural fibers, which must be overcome to meet the needs of customers who want pure natural fiber products. The *market demand* is driven by product quality and therefore the quality of these natural fibers must continuously be improved. And finally the *price* of these natural fibers must be reasonable for the demand and for farmer's economic basis (Alex et. all, 2004). In times of steadily rising oil prices and increasing scarcity of cotton, the potential for bast fibers such as hemp, flax, tobacco and kenaf have the potential to breach the market, as a substitute or as blending fibers for cotton (Theilmann, 2010).

In order for sustainable, eco-friendly fashion to succeed in the industry and compete against the many fast fashion brands there must be great attention brought to the branding and marketing of eco-friendly, or ethical fashion brands. Beard (2008) looks at factors that have influenced and discovered that fashion has been one of the last industries to embrace the environmental and human costs of its impact on society, because the apparel market is largely saturated with fast, cheap and readily available fashion. Beard introduces the importance of eco-fashion branding not only as "ethically worthy, but increasingly as fashionable not just to a niche audience, but to everyone" (Beard, 2008). According to Beard, consumers are becoming more and more concerned about the environmental impact their purchasing decisions have on the earth and the people around them. The environmental trend is heading in the right direction for the apparel industry, however, the barrier arises from the availability of trendy, clothing that are extremely cheap and are associated with guilt free disposal (Beard, 2008). This behavior derives from the advertising and promotional strategies of eco-fashion brands. Terms such as *ethical*, *fair trade, organic, natural, sweatshop free, recycled* and *second-hand* or *vintage* are used in persuading customers to see their brand as environmentally friendly, and ethically sound. The overuse of these terms results in consumer confusion or misunderstanding of what the brand is promoting. This phraseology is one of the most important aspects of relating the brands to their consumers and must be handled with care in order to eliminate the confusion of the market and of the firms themselves (Beard, 2008). Although there are several trade associations that are working towards clarifying ethical practices amongst commercial firms, this may aid to the confusion, because there is no single organization to recognize the "ethical" fashion industry (Beard, 2008).

Because the apparel industry is becoming so saturated with fast fashion, this is aiding the interest of more unique, higher quality and environmentally conscious products. There has been a move in the direction of a more well-rounded quality of life, which sheds light on the simpler, more personal connection to supporting local artists/designers and farmers, as well as the popularity of shopping at second hand, or vintage stores. Alexander Palmer suggests vintage has now shifted from subculture to mass culture because of the disappointing fact that, regardless of price, fashion today is rarely exclusive (Palmer, 2005). This relates to the interest in *one of a kind pieces* discussed in Young's (2004) article and demonstrates the possibility of the one of a kind, and personalized niche companies remaining prevalent in the market. Although the important aspect of aftercare must be examined, while many second-hand clothing items entail dry cleaning, which negates the ethical aspect of the purchase (Beard, 2008). This is an important position for ethical clothing firms to examine, as the aftercare aspect of clothing is said to have the "most demonstrable negative impact on the environment as a whole" (Beard, 2008. P. 452). Many eco-friendly apparel outlets tend to produce casual everyday apparel such as basic t-shirts, which will fit into anybody's existing wardrobe. Although in part, this relates to the standstill of the industry, because many people won't pay more for such basic items just for the ethical benefit, not to mention, people are still expected to wear more formal clothing for work. The breach of this market will be important for eco-fashion brands to gain importance and popularity among a larger market. Important aspects for the eco fashion industry to increase market share potential are that, they must: be transparent to consumers in all areas of their business, provide clarity to the benefits that are included in purchasing their product, and inject a greater stylishness into their collections (Beard, 2008).

Sustainable and design, two concepts that can include many different aspects, are central to the development of a more environmentally aware textile market. Design must include product developer's decision making about materials and manufacturing facilities (Thomas, A., 2009). If product developer's chose environmentally friendly materials as well as implemented sustainable practices throughout their supply chain, then, true to the definition of sustainable development, they would not be compromising the needs for future generations and they would be satisfying their own need presently. This development of sustainable products would therefore allow adequate standard of life throughout the world, that would not damage the worlds environments, this has been conceptualized to incorporate three elements; economic, environmental, and social (Thomas, A., 2009). Although, literature on sustainable development shows mostly the importance of using environmental materials and the energy and water consumption of the processing of those materials, design, of a certain sort can aid in the sustainability of a product. Purvis, 2004, states that

> *'some products can be redesigned to increase their eco-efficiency; others must be replaced with environmentally sound alternatives. In both cases, environmental considerations should be integrated into the design process… Design for environment stresses not only resource efficiency and clean production technologies, but also recycling at the end of its lifespan' (Purvis, 2044, P. 161-162).*

2.9 Sustainability of bast fibers

Hemp fibers are a possible crop that can benefit from a move in the direction of creating a more sustainable industry for textile and apparel production. Although these fibers are not yet legal for cultivation in most of the U.S., there is a substantial debate regarding the practicality of growing industrial hemp as a fiber alternative in the United States (Lin, 2005). Hemp is a fiber that can contribute to the three spheres of sustainability, economic development, social development, and environmental protection. This fiber is sustainable and offers environmental protection. Hemp is grown with little or no pesticides, is resistant to most insects and fungus, improves soil fertility (extracts pollutants such as zinc and mercury) and is a durable rotation crop that can sustain and adapt in most climates. Hemp cultivation yields more paper per acre then trees, uses less water consumption then cotton, growing time for hemp is approximately 120 days, and the yield is 20%, which is 600% greater than cotton and flax.

Hemp has also been said to be the strongest and most durable of the natural fibers (Lin, 2005). Potential economic contribution of growing hemp in the United States is diversification of crops for farmers, as well as the ability to increase employment, personal income levels, and net imports. Hemp can be grown for multiple end uses, which in turn utilize the entire plant, which reduces waste creation. Hemp can be grown for the fiber (for apparel and interior textile products), paper, cosmetics, carpets, salad oils, snack construction materials, biodegradable auto parts and hormone free, steroid free and anti-biotic free hog food, as well as in other industrial products (Lin, 2005). Within Lin's study, it was found that hemp could be a potential substitute for hay production and would produce more jobs and greater sales (2005, p.13). There are many debates regarding the production of hemp, because of the concern with the aspect of Tetrahydrocannibinol (THC), more commonly related to the negative stereotype associated with marijuana. Although hemp has little traces of THC, the government, if hemp cultivation were legalized, would have little ability to regulate or control the growth of the Marijuana. Sustainably and economically, however, there is a definite array of benefits that would come from making the cultivation and growth of hemp legal within the United States (Lin, 2005). Although hemp has restriction in the US, flax has no such restrictions and therefore could have even more potential for production and commercialization. Because of the rising oil prices as well as the low supply and high demand of cotton, companies have begun to search for alternative materials to use in their products. There has been an increasing interest from spinners, knitters and manufacturers in the new fiber CRAiLAR® created by Naturally Advanced Technologies Inc. (N.A.T.). CRAiLAR® is an organically certified fiber derived from bast fibers such as flax, hemp, jute and kenaf which are responsibly treated with an enzymatic bath and then spun into soft, white fibers similar to cotton. This fiber is created by NAT, and supported by the National research council Canada, is likely to take a front spot in the global apparel knit market because of its recent partnership with Hanes brands. This fiber is said to be the first truly sustainable yarn in the apparel industry, which will prove to be a potentially huge advancement for bast fibers in the textile industry. CRAiLAR® yarns can be used in knit, woven and nonwoven fabrics alone or in blends, and is appropriate for mainstream or alternative apparel and fashion fabrics, as well as industrial uses. CRAiLAR® fabrics have been tested to be of high quality and ideally appropriate for fine knit items. CRAiLAR® will be available for .90 cents/pound which is economically feasible as an alternative to current cotton (which is over a dollar) (Naturallyadvanced.wordpress.com, 2010).

The CRAiLAR fibers have been developed with flax and hemp fibers and both materials prove to be sustainable, and have similar or better properties then organic cotton (Natural Advanced Technologies, 2010). The CRAiLAR® flax is soft like cotton, similar in color, possesses similar performance traits and is cool and comfortable to wear year round. The wash ability of CRAiLAR® flax is the same as cotton, but CRAiLAR® flax shrinks less, wicks moisture better, and has increased dye uptake, which means less chemicals are needed to reach the same color levels. This advanced material and process using the enzymatic bath actually increases the properties of the flax fiber. Flax contains glue-like lignin and pectin which is what creates the stiffer hand of traditional flax fabrics, The CRAiLAR® process removes these glues, which dramatically improves the texture, color, and performance capabilities. The yarns and fabrics can also be produced on existing cotton machines (Natural Advanced Technologies, 2010).

The paper pulp industry has been criticized for the negative effects on the environment. The cotton industry has also been in the media because the high use of pesticides, high fertilizers, and irrigation requirements. These issues could be reversed with the introduction of a hemp industry for paper pulp and textiles (Van der Werf et al., 1996). This would be beneficial because of less energy conservation, less land usage, and reduced water consumption. The use of hemp for paper products lessens the need of deforestation, reduces emissions of chemical waste, less energy is used to produce pulp from hemp, and the lignin content of hemp is lower, opening up the possibility of using less bleach or creating unbleached pulp. Hemp also requires little to no pesticides and fertilizer requirements are modest. Hemp is also said to fit into sustainable farming systems and has a high fiber yield. Van der Werf categorizes both bast fibers of Ramie (for warmer climates) and Kenaf (for the production of pulp for paper) as increased sustainable options for textile and paper crops. Flax is also a valuable crop for textile and specialty paper production. Flax fiber is the highest priced bast fiber, which makes it have slightly less of a demand from the market. Hemp is the most durable and has the fastest cultivation for any weather making it an attractive addition for a more sustainable textile and paper pulp industry (Van der Werf et. all., 1996).

The move towards a more sustainable market is prevalent in not only the textiles industry, but also with the food industry and automotive industry as well. With the push in the direction of sustainability, natural fibers, specifically bast fibers have begun to be used in the production of composites for automotive. Flax fibers are being used in composite materials in the automotive and constructive industry. Bio-composites are composed of flax fiber based on polyhydroxybutyrate (PHB) polymer and have the potential to become an eco-friendly and biodegradable alternative to conventional plastics (Jhala, 2010). Increasing costs of artificial fibers, increased awareness of environmental footprint, and advantages of using natural flax makes it a model fiber in move towards a more sustainable future in the textile industry. As new technology and equipment for growing, and harvesting flax plants make each stage of production more efficient which will aid in the possible upturn of market demand and usage of flax fibers as well as other bast fibers (Jhala, 2010).

Several Life Cycle Analyses have been completed for hemp and flax bast fibers, and these analyses would be applicable to other bast fiber products as well. A Life Cycle Assessment (LCA) is used to assess the environmental impacts and resource utilization of a product. This is done by quantifying and evaluating the resources consumed, and the emissions to the environment from all stages of its life cycle. This includes extraction of resources, to production of materials, product parts, to manufacturing of product itself, and the use, reuse, and final disposal of the product (Van Der Werf, 2004).

The life cycle of a bast fiber is shown in Figure 11. This was demonstrated as part of the LCA of the HEMP SYS project conducted by the European Union in 2002. All factors must be evaluated for input and output throughout the process chain of manufacturing a fiber. This figure shows the stages of the energy use and pollution created by manufacturing of these fibers.

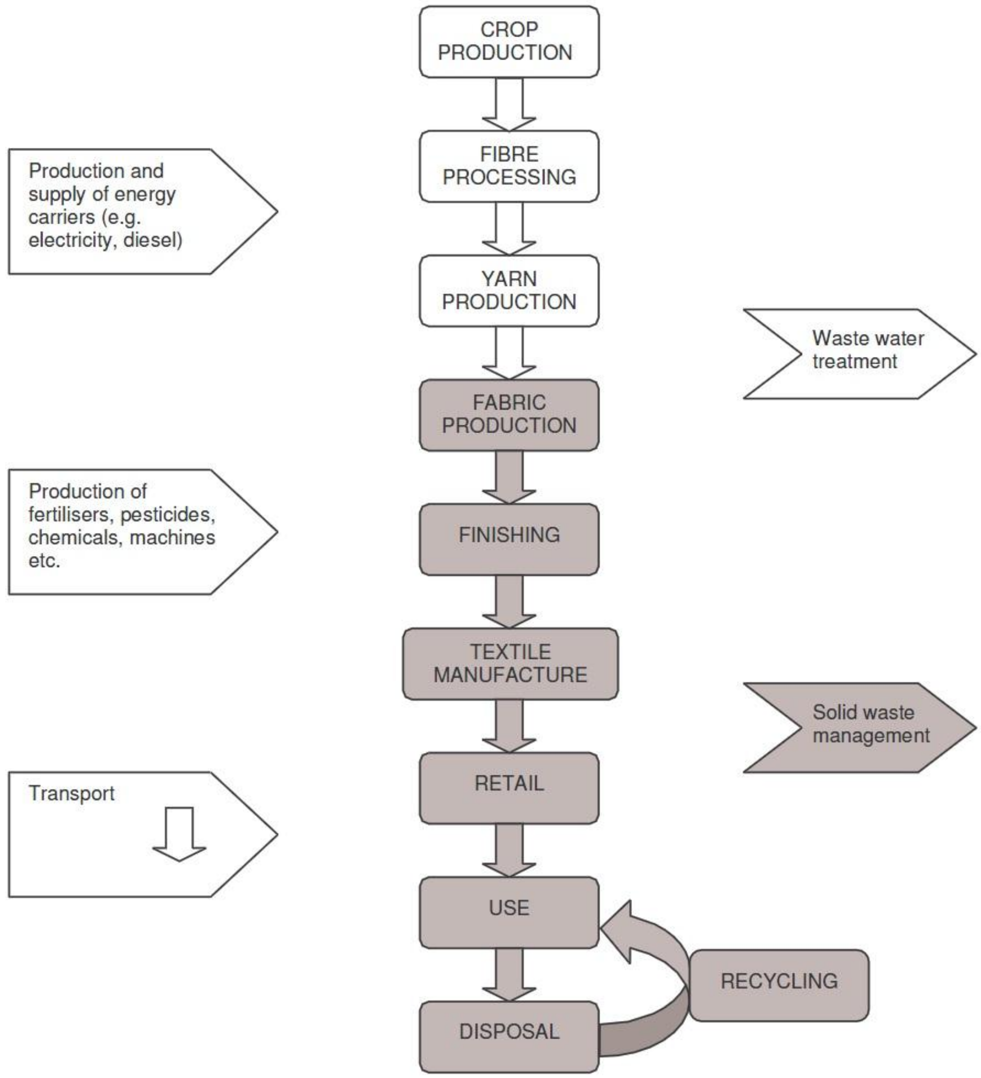

Figure 11: The main stages of the life cycle of (bast fiber) textiles
Source: Turunen, l., Van Der Werf, H., 2006.

Each of these stages is composed of many smaller, successive operations. There are many alternative production techniques and methods, making it hard to demonstrate one standardized textile production chain. Figure 11 shows the main stages of the processes that make up the life cycles of textile production.

The following tables (4-6) will show some comparisons of properties and characteristics of bast Fibers compared to cotton fibers.

Table 4: Hemp, flax, and cotton comparisons

Component %	Hemp	Cotton	Flax
Cellulose	77	90	76
Lignin	9	0.5	11
Moisture	9	8	9
Ash	1	1	1
Other	4	0.5	3

Table 5: Hemp, flax, cotton comparisons

Property	Hemp	Cotton	Flax
Color Range	Yellow-Brown	White	Yellow
Breaking Length	86,000	58,000	85,000
Percent Elongation	1.8%	3%-10%	2%
Average Stiffness (g/gx)	200	56	270
Heat Capacity	0.323	0.319	0.321

Table 6: Alternative plant fibers compared to cotton

Fiber Name	Absorbency	Abrasion Resistance	Machine Washable	Wet Strength	Drape	Hand
Flax (linen)…	Excellent	Excellent	Yes	Excellent	Fair	Fair
Cotton	Very Good	Very Good	Yes	Very Good	Good	Good
Jute	Excellent	Excellent	Yes	Fair	Fair	Fair
Ramie	Excellent	Excellent	Yes	Fair	Fair	Fair
Hemp	Excellent	Excellent	Yes	Excellent	Fair	Fair

Note: New finishing techniques are improving hand and drape of flax and other
Source: Baugh, 2008

CHAPTER 3: METHODOLOGY

The purpose of this research was to investigate bast fibers and their potential for high value added products in the sustainable textiles industry. Consumer's response to this type of textile product was tested through a subjective fabric hand evaluation method. Specifically, this research evaluated each participant's response to sensory perception of these types of materials and their potential to gain market acceptance in the apparel industry.

This research was conducted in two phases;

1. Phase One of the research was conducted through informal interviews with textile professionals and companies. The objectives of these interviews were to determine 1) what type of products would be appropriate for bast fiber materials, 2) whether or not the industry or the specific companies were using bast fibers or interested in these types of fibers. In addition, during the Phase One interviews process, the Principal Investigator (PI) sought the industry members advice on suitable methods and materials for the to validate the physical hand evaluation that was administered in Phase Two.
2. Phase Two of this research consisted of the development and administration of a subjective hand evaluation that compared the sensory perception of selected bast fiber fabrics with two commercially used fabrics. One 100% cotton (non-sustainable fabric) and one 50% recycled polyester/ 50% organic cotton (sustainable fabric).

3.1 Research Objectives and Questions

Phase One is primary data collected by the principal investigator and resulted in qualitative data collection. Phase One included;

- Informal interviews with three companies in the textile industry
- These interviews distinguished what the companies views on bast fibers are, whether the companies have used bast fibers in their products, and the company's opinions about the potential for bast fibers in the textiles industry.

Phase two was conducted using a mixed method research technique (qualitative and quantitative) and resulted in a statistical analysis as well as qualitative results. Phase Two included;

- Adapt and utilize a material testing procedure to determine sensory perception of bast fiber materials compared to one another, and to other materials, through a physical fabric hand evaluation procedure.

The following questions were answered through this study;

Phase One research Questions:

RQ1: Are companies currently using bast fibers in their products, why or why not?

RQ2: Are bast fibers a viable option for the sustainable apparel industry according to industry members?

RQ3: Is the survey instrument (for Phase Two) thorough and comprehensive for evaluating bast fiber fabrics compared to other fabrics in the industry?

RQ4: What types (content, structure, weight) of fabrics would be beneficial to use in the survey instrument (used in Phase Two).

Phase Two research questions:

RQ5: How do bast fiber knit fabrics rate in comparison to one another and to other fibers for comfort and fabric attributes (cool/warm, dry/wet, smooth/rough, bald/hairy, thin/thick, flexible/stiff, stretchy/non-stretchy, Comfortable/uncomfortable)?

RQ6: How do bast fiber fabrics rank in comparison to one another and to other fibers in the use of a tee shirt (product distinguished in Phase One)?

3.2 Phase One: Company Interviews

The objective of Phase One of the research was to obtain information from three companies in the industry to distinguish their thoughts and opinions surrounding bast fibers for apparel textiles. Phase One of the research consisted of informal interview method that was conducted in a series of phone calls. The companies were interviewed first in order to determine industry response to bast fiber textiles. The informal, conversational interviews described three companies' experiences, opinions, and knowledge on the potential use of bast fibers in the textiles market, specifically in the apparel market. Another objective of Phase One was to gain more personal data from the interviewees regarding their company's relationship, thoughts, and awareness of the bast fiber materials. The interviews were also used to obtain company's opinions and validation on the physical hand evaluation survey that would be administered in

Phase Two, and to obtain valuable insight into the appropriate fabric types and end product to utilize in the survey instrument.

3.2.1 Company selection

The principal investigator chose to target companies that were interested in sustainability and natural fibers and who were interested in participating in interviews for this study. It was also important to talk to companies that may be interested in, or are already using bast fibers or other forms of more sustainable materials. The companies were chosen based on their position in the industry. All three were interested in sustainability, natural fibers (or bast fibers specifically), and product development. Companies were also chosen based on relationships previously formed between the companies and North Carolina State University faculty as well as the companies' interest in the research and their willingness to participate.

3.2.2 Company profiles

Three companies were interviewed to understand their opinions and usage of bast fibers within the apparel industry. Backgrounds on these companies are as follows;

Company A, started in 1899, is a leading apparel brand primarily serving the image wear and private label markets. Most recently ranked as one of the top largest organic programs in the world by The Organic Exchange. Company A sells a variety of t-shirts and accessories as well as promotes organic and sustainable programs internationally. They emphasize learning about the environmental impact of a t-shirt form farm to consumer. Participants from this company included the Executive Vice President of the company, the Head of Sustainability and Social Media, and the Vice President of Innovation and Product Development.

Company B, started in 1993 is the world's largest supplier of hemp products from fabric to body care. This company sells wholesale and retail. Company B strives to provide manufacturers, companies, designers, students and individuals with the knowledge and resources necessary to utilize hemp effectively in their project. The CEO of Company B participated in providing insight and information in the interview process.

Company C, since 1970, is the world's largest cotton research center. From agricultural, fiber and textile research, market information, technical services, advertising and public relations, to fashion forecasts and retail promotions, this company keeps cotton on the forefront of design and innovation. The manager of product development form company C participated in this interview as well as the Head Textile Chemist for Textile Finishing Research.

These three companies contributed information and fabric for the use in this research project. All three companies were asked to sign a consent form validating their responses before their responses could be added to the results of this research. Please see APPENDIX A for Informed consent form from industry members.

3.2.3 Data collection and analysis method

Data collection for Phase One of this research was generated through personal communication, phone and email interviews with Companies A, B, and C. This qualitative data was recorded by written methods and then typed up for analysis and review. No other recording devices were used. The data from the three company interviews were compared to each other to determine similarities and differences. Results and meanings were evaluated by the principal investigator.

3.4 Phase Two: Physical Fabric Hand Evaluation

The objective of Phase Two of this research was to adapt and utilize a survey instrument to determine sensory perception of bast fiber materials compared to other materials through a subjective hand evaluation procedure. The term *hand* has been defined as the subjective assessment of a textile obtained from the sense of touch. Hand is concerned with the subjective judgment of roughness, smoothness, harshness, pliability, thickness etc. (Denton and Daniels, 2002).

3.4.1 Development of fabric hand evaluation

The development of the physical hand evaluation procedure was conducted through two vital sections. First was the determination of the materials to be used within the survey, and the second part was the development of the survey questionnaire. The process that was used to narrow down these aspects is explained in detail below.

3.4.1.1 Determination of fabric samples

In Phase One of this research Companies A, B, and C helped to distinguish what fabrics would be appropriate to test in the fabric hand evaluation survey. The principal investigator determined through the interviews that all of the fabrics would consist of jersey knit construction, of a suitable weight for a tee shirt. A t-shirt was deemed an appropriate end product to evaluate because this type of end product is worn against the skin, therefore hand is particularly important. The end product was also decided upon because a tee shirt is a well-known commodity product for every age, ethnicity, and gender therefore it would be applicable to all evaluators that participate in the survey (Laun, 2011). The inclusion of several types of bast fiber fabrics was essential to the research. Fabric A and Fabric B were recommended by Company B to be part of this study, and Company B provided a discount in the fabric price in support of the research. Fabric D was donated from Company C, and recommended as a traditionally used fabric for a typical cotton tee shirt already commercially used. Fabric C was bought by the principal investigator for inclusion of another type of pure bast fiber fabric. Fabric types were recommended to get a range of different commonly used materials for tee shirts, and a range of sustainable materials and bast fiber materials used for tee shirts. Table 7 describes the five fabrics that were used in the study. All fabrics were chosen to be within a weight range appropriate for t-shirts (4.5oz/yd^2-6.8 oz. /yd^2) which was established by an extensive market evaluation by online search of tee shirts currently in the market, and validated by industry professionals in tee shirt production companies.

Table 7: Test fabrics and properties

Fabrics	A	B	C	D	E
Fiber Content	55% hemp/ 45% organic cotton	100% hemp	100% linen	100% cotton	50% recycled polyester, 50% organic cotton
Weight (oz./yd^2)	6.5 oz./yd^2	6.8 oz./yd^2	4.72oz./yd^2	5.2 oz./yd^2	4.8 oz./yd^2
Knit structure	Jersey Knit	Jersey Knit	Jersey Knit	Jersey Knit	Jersey Knit
Yarn type	21s/2 yarn	36 NM	unknown	18/1ne	30/1 yarn,
Twist	Alternating s and z twist	Alternating s and z twist	Alternating s and z twist	Alternating s and z twist	Alternating s and z twist
Spinning method	Ring spun	Ring spun	Ring spun	Ring spun	Ring spun
Finishes	Hydrogen Bleach bath	Hydrogen Bleach bath	Bleached	Dyed and cotton soft 200 formula applied	Dyed and Softener applied

3.4.1.2 Development of survey

While there is not one industry standard for subjective fabric hand evaluation several publications have noted similar subjective hand evaluation procedures that were used and adapted for this study. These publications included *Can Fabric Hand Enter the Data space* by John S.W.S Hearle (1993), Study *on the Hand* by Takashi Harada et al, (1971), *The Handle of Cloth as a Measurable Quantity* by F.T. Peirce, *Development of Terminology to Describe the Hand Feel Properties of Paper and Fabrics* by Civille, G. V.

and Dus, C. A. (1990). *AATCC Evaluation Procedure 5, Guidelines for the Subjective Evaluation of Fabric Hand* (2001), as well as others cited throughout this paper.

The survey (APPENDIX B), was created through a web based survey tool, and consisted of three separate parts; 1) a fabric hand rating section, 2) a fabric hand ranking section and 3) a section that asked general questions on consumer purchasing habits and demographics. All sections were tested at one appointment time with the evaluator. The experiment was conducted as a blind study; therefore no visual aspect of the fabric affected the subject's opinions on the handle of the different fabrics. Due to the use of human subjects, the study was not conducted in a climate controlled environment, although all testing was done in a designated area within the textiles university and temperatures and percent humidity were recorded during each testing period to make sure they did not fluctuate more than three degrees in either direction. The subjective hand analysis survey questions for this research were developed in accordance with AATCC evaluation procedure 5 (2006), and guided by peer reviewed research publications and literature. Once the initial hand evaluation methodology was developed, an expert from Textiles Protection and Comfort Center assisted in reviewing and refining the testing instrument and procedures.

The attributes that were evaluated through this research included cool/warm, dry/wet, smooth/rough, bald/hairy, thin/thick, flexible/stiff, tight/stretchy, comfortable/uncomfortable. The rating section of the survey used both qualitative and quantitative questions to obtain the data. For each attribute a 5 point Likert scale was used to allow the participants to rate the fabrics for their demonstration of that particular property; after each rating scale was given, evaluators were asked to give any additional comments they may have had about that particular attribute and fabric type. These open ended questions were added for clarification or additional qualitative data that may be helpful in the data analysis process.

For example for the cool/warm attribute the 5 point Likert ratings were 1-very cool, 2-somewhat cool, 3-neither cool nor warm, 4-somewhat warm, 5-very warm. Evaluators were also asked to rank the fabrics from most desirable to least desirable fabric for a given photo of an end product. The end product was a basic tee shirt.

The concept of measuring physical properties of fabrics and associating them with the handle of fabrics was introduced in 1930. Traditionally testing fabric hand focused mostly on various strengths such as tensile, tearing, and bursting strength in relation to fabric failure. These standards have risen and it has become more common to select or discard fabrics based on their overall performance and wearing functions. The most sophisticated mechanical testing equipment that has been developed for the purpose of measuring these properties is the Kawabata Evaluation System for Fabrics (KESF). The Kawabata system can detect the following properties; bending (bending rigidity and hysteresis of bending moment), surface (coefficient of friction, mean deviation of MIU. Geometrical roughness), tensile (linearity of tensile curve, tensile energy, tensile resilience), shearing (shear stiffness, hysteresis at 0.5°, hysteresis at 5°), compression (Linearity of compression curve, compressional energy, compressional resilience), thickness (Fabric thickness), and weight (fabric weight) (Ning Pan, et al. 1993). Although this system measures many parameters and reduces data analysis time considerably; the Kawabata system is expensive, complex to operate, and relatively inaccessible (Ning Pan, et al, 2010). The KESF system was developed and configured for woven fabrics and are not well suited for testing lightweight knits, although they are still tested on this equipment when necessary (Mahar, et al., 2010).

The survey created for the evaluation of the fabrics used in this research was developed to gain results based on the hand of these fabrics. This information was achieved by asking subjects to rate the fabric based on the attributes displayed in table 8 (which relate to both mechanical testing characteristics and the characteristics found to be most descriptive when evaluating by hand). Table 8 shows the physical hand attributes and the mechanical testing equivalent.

Table 8: Subjective and mechanical measurement equivalents for fabric hand

Physical Hand Evaluation Attribute	Mechanical Hand Equivalent	Mechanical Testing Apparatus
Cool/Warm	Surface Property	Qmax
Dry/Wet	Absorption property	Vertical Wicking, MMT, GATS, Drop test
Smooth/Rough	Surface Property (Coefficient of friction, Geometrical roughness)	KES-FB4
Bald/ hairy	No Mechanical equivalent	N/A
Thin/Thick	Bulk Property (Fabric thickness)	KES-FB3, Compressometer, Calipers, or balance
Flexible/Stiff	Flexural Property (bending rigidity, hysteresis of bending moment, Shear stiffness)	KES-FB2 or KES-FB1
Stretchy/Non-stretchy	Flexural Property	KES – tensile, instron
Comfortable/Uncomfortable	No Mechanical Equivalent	N/A

The survey and survey materials were assessed and validated by expert in the comfort and protection field, at The Textile Protection and Comfort Center (TPACC) at North Carolina State University, College of Textiles. The survey was also evaluated by professionals in the companies that were interviewed in Phase One.

3.4.2 Administration of physical fabric hand evaluation

After the development and validation of the survey instrument, the administration of the survey was carried out. The procedures for the administration of the Physical Hand Evaluation were as follows: Institutional Review Board (IRB) evaluation and acceptance, population and sample recruitment, and survey administration.

3.4.2.1 Institutional review board exemption

After the testing procedure development was finalized the entire process was evaluated and approved by the IRB for the protection of human subjects in research divisions. The IRB Board must approve the entire procedure to protect the rights and welfare of human research subjects through project review. The IRB is also responsible for fostering compliance with institutional policy and federal regulations by facilitating institutional personnel's efforts in utilizing living human subjects for research, education and other scholarly pursuits that are systematically designed and endeavoring to contribute to generalizable knowledge. Overall the IRB helps scientists and institutional personnel know how to ethically and safely use human subjects (IRB Mission Statement, NCSU, 2012). Please see APPENDIX C for IRB exemption form and APPENDIX D for IRB approval.

3.4.3.2 Population and sample

A convenient sample was used for this research. The research objectives of this study were to analyze the response from the evaluators for textiles produced from bast fibers. It was important to target individuals who were likely to be involved in the textiles industry and who could give more informed responses to the attributes that were being asked about each fabric. For this reason, a convenience sample was appropriate for this research because the subjects for this study consisted of students who attended a textiles university. The convenient sample was also appropriate for this research because the majority of the evaluators fall into the 18-25 year range. According to research by Amy Laun, (2011) the largest consumer population of tee shirts is age 16-36 (Laun, 2011).

Subjects for this study were recruited by sending out department emails to both undergraduate and graduate departments. Emails were also sent out to teachers requesting time in their classes for the principal investigator to speak to students for the purpose of recruitment to complete the evaluation. A small population of people who work in the department or who are professionals outside of the university also responded. APPENDIX E shows the recruitment emails that were sent out to the undergraduate and graduate departments. APPENDIX F shows the emails that were sent to individual teachers to request time in classes to recruit participants for the study.

3.4.3.3 Testing materials and equipment

Fabric samples for the evaluation survey were prepared according to guidelines followed by the AATCC Evaluation Procedure 5- 2006 Fabric Hand: Guidelines for the Subjective Evaluation Of (2001). For the purpose of this project, certain procedures were adapted to better work for the scope of this study. Each fabric type was cut into 8x8 inch squares, and enough samples were prepared to give each subject their own set of 8x8 in. fabric squares of each type of sample fabric. Each fabric was then marked by ink to identify the fabric ID, no attached tags or labels were used to identify fabric so that it would not interfere with the evaluation process. According to the AATCC evaluation procedure 5 (2001), the specimens must be conditioned under reported relative humidity and temperature. These climate conditions were recorded during each of the evaluation sessions, and were kept at a relatively constant rate as to not affect the evaluation procedure or samples. Temperature and humidity were recorded at 72° F (+/-3) and 41% humidity (+/-5). Each of the fabrics were washed preceding the evaluation procedure to ensure similar care to each of the fabrics.

The prepared fabric samples were then put into a random order through a statistical randomization formula (see APPENDIX G). The randomization was done by using R, a mathematical program. The randomization formulas distinguished the permutation of ABCDE. The sample number was distinguished as 120 participants, which had no overlapping sequence with the 5 fabrics. The statistical equation that was used to identify the permutation was;

```
x= sample (120, 120, replace=FALSE, prob=NULL)
A = as.matrix(X)
```

The formula randomized the fabric types (A, B, C, D, and E) 1 through 120 without replacement. The randomization sequences will make sure that no fabric will be subject to fatigue, if for example this sample was always tested last, nor will they be compared against one another in the same order. The randomization table was then used for the testing procedure. This will ensure that the order of the fabrics will not be a variable in the results.

The testing equipment consisted of four wooden test boxes that blocked the evaluators view from the fabrics as they evaluated the fabrics for each attribute. Each of the four boxes was exactly the same, and created the ability to test up to four evaluators at one time. The test box was designed with a closed front in order to block the evaluators view from the fabrics that are being evaluated. Either side of the box was designed with an opening large enough to accommodate their hands without discomfort. The back of the box was left open so that the proctor could easily change the fabric sample that was being evaluated. The box was sturdy enough to hold a computer which had the survey questions loaded onto it for the duration of the testing procedure.

3.4.3.4 Evaluation procedure

1. As suggested by the AATCC procedure 5, each evaluator was instructed to wash their hands prior to touching the fabrics. The evaluators used non-moisturizing soap and dried their hands with paper towel. The evaluators acclimated to the temperature and humidity of the testing facility while the proctor walks them through a brief explanation of the testing procedure (~ 2 min).
2. Evaluators were then asked to sign a consent form releasing their responses and demographic information for the use in this study (See APPENDIX G for

consent form). Evaluators were not exposed to drastic temperature changes or extreme exercise before participating in the study.

3. The first part of the survey involved rating each of the fabrics on a 5 point Likert scale. The fabrics were presented to the evaluator, one at a time, in random order. The samples were out of view to the evaluator during the experiment by using the testing box, with each of the sides open for their hands. The front of the box was closed so that no view of the fabric was possible. The proctor placed the fabrics in through the back of the box where there was an opening to place and remove samples. The evaluators were asked to rate each of the fabrics based on comfort/discomfort and seven fabric attributes; Cool/warm, dry/wet, smooth/rough, bald/hairy, thin/thick, flexible/stiff, and stretchy/non-stretchy.
4. After the evaluator completed evaluating each of the five fabrics, the evaluators were shown a picture of a t-shirt (see Figure 14). They were then blindfolded, and the five fabric samples were placed on the table in front of them in random order. The tables are all the same non-textured, non-metal surface. The evaluators were then asked to rank the fabrics in order from the most desirable to least desirable fabric for the image. The ranking was recorded by the proctor and the fabrics were removed from view. This section was conducted with a blindfold so that the color/look of the fabric was not a contending variable in this decision.

5. The last part of the survey asked the evaluators several questions on their purchasing behaviors for sustainable apparel.

Figure 12 shows the product image that is shown to the evaluators during the ranking section of the survey.

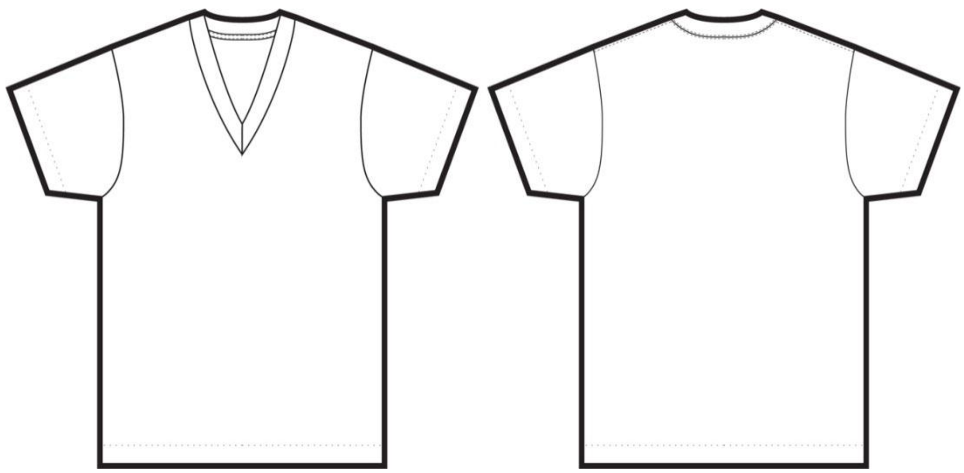

Figure 12: Product Image used in part two of survey: Ranking

3.4.3.5 Data collection

Data for Phase Two of this research was collected using an online survey tool and analyzed using SAS statistical programing. Statistical analysis was conducted in collaboration with two hired statisticians and the principal investigator. Statistical results were recorded and analyzed by principal investigator. Qualitative data from Phase Two was analyzed by the principal investigator by means of a content analysis and identification of themes, patterns, and categories.

CHAPTER 4: RESULTS AND DATA ANALYSIS

4.1 Phase One Results: Company Interviews

The main results obtained from Phase One of the methodology fulfilled the research questions;

RQ1: Are companies currently using bast fibers in their products, why or why not?

RQ2: Are bast fibers a viable option for the sustainable apparel industry according to industry members?

RQ3: Is the survey instrument (for Phase Two) thorough and comprehensive for evaluating bast fiber fabrics compared to other fabrics in the industry?

RQ4: What types (content, structure, weight) of fabrics would be beneficial to use in the survey instrument (used in Phase Two).

The interviews aided the principal investigator in determining if companies are using bast fibers in their companies, and why they were or were not using it currently. The interviews also distinguished whether bast fibers were a viable option for the textile industry and in what product category they would work best. Companies also aided in the narrowing down of the survey instrument questions and types of materials and end product to be used in the survey instrument in Phase Two.

4.1.1 Company A analysis

Informal Conversational Interview Questions/answers:

1. **Does your company use any bast fibers, or plan to use bast fibers, in their products? If so what advantages/disadvantages have you found?**

Company A is highly motivated to incorporate more sustainable materials and implicating sustainable practices within every aspect of their company. Although Company A has not yet manufactured any products that incorporate bast fibers, the company has looked into incorporating bast fibers, specifically hemp and flax fibers as an alternative sustainable material for their product lines. Company A's research and development team has explored using these fibers on their own and as a blend. The research and development team believes that incorporating a fiber such as hemp would add a premium to their products, because of its level of sustainability. The company's main motivation for using hemp is that hemp would create a more sustainable product. Company A stated that although the costs of raw material (hemp) is higher than other natural fibers, consumers are willing to pay a higher price point due to the perception of hemp as a more sustainable material (personal communication, 2012). The company credits hemp to having a good sustainable story therefore giving it more credibility to the eco consumer. Some disadvantages that the company has encountered through their research and sample development include the drape of the fabrics not being as satisfactory as what they desire for their products. Company A stated that although the drape of hemp fabric is actually quite nice, in certain blends the high drape can cause a more fit conscious appearance, which is not always suitable for casual active wear. Company A blended their fabric with recycled polyester and *has developed a fabric with an ideal drape and hand. Company A also commented on the difficulty of processing hemp as being an issue in market acceptance. Because cotton is so widely used and produced, it is easy and less expensive to acquire and incorporate into products. The fact that hemp cannot be grown and processed in the United States makes the ability to incorporate it into their products more expensive and more difficult. Through research and sample development Company A concluded that certain properties of the hemp and flax don't lend themselves to certain properties needed for their particular sportswear, but when blended with other materials (i.e. cotton and other fabrics) they have better properties and are very plausible materials. In conclusion, Company A continues to view bast fibers as a very probable material to incorporate into their products but, as with any product development, the company must first look into the retail sensibility and attractiveness to the consumer before incorporating it.*

2. **Do you know of any other companies who are incorporating bast fibers into their products?**

   For knit products, such as t-shirts, as well as other types of products?

   The company does not know of any direct competitors of their size and magnitude that are incorporating bast fibers into their product lines. This lack of competition presents a potential market opportunity for them, but is also a sign that further development must take place in order to incorporate these materials.

3. **Does your company do any form of hand evaluation testing for their fabrics that they use?**

   If so, what types of questions are assessed/give the best results? What is the evaluation process?

   Company A conducts informal marketability testing of fabrics that are in final development stages before going into production, and also conducts marketability scans to measure the fabrics potential for acceptance in the market. In addition, Company A tests certain properties that they know buyers, companies, stakeholders, and other subjects will ask about. Factors that the company finds important to test include; 1) printability with several forms of printing including digital printing, sublimation printing (dyeing), and other dyeing and coloring techniques. 2) wicking properties, 3) shrinkage, 4) pill tests and 5) burst strength. After the company initiates these tests within their own R&D departments the company conducts a very informal tactile test, where the company simply passes the fabrics around at a meeting and gather reactions and responses to initial touch, feel and sight. After new materials have made it into the manufacturing stage, occasionally a wear test is conducted before products are released into production. Once released into production annual audits are conducted by the technical product development team. No formal hand tests are done.

4. **What weight range and fabric structure is most commonly used in your tee-shirt products?**

Company A's fastest growing fabric weights is 4.5oz/sq. yd., however Company A stated that their most commonly used fabric, based on volume, is a 100% cotton 5.4oz jersey fabric. Company A's full range of tee shirt weights ranges from 4.5 oz./yd^2 to 6.2oz/yd^2.

5. **Would your company be interested in helping out this research in any way? (i.e. Possibly donating fabric yardage that you think would be a good comparison fabric for this research, specifically any that are bast fiber blends or sustainable if applicable, otherwise, the most commonly used fabrics).**

Company A was very interested in participating in the physical hand evaluation survey and donated Fabric E to be incorporated into the physical hand evaluation in phase three of this study. Fabric E, an organic cotton/ recycled polyester blend, is one of their more common materials used in their products.

6. **Other questions that you think would be beneficial to this research that should be asked to evaluators in the hand evaluation study?**

Company A suggested the inclusion of the last questions in the survey, determining consumer willingness to pay for more sustainable products. Company A thought that the tee shirt was a good product to test because of its popularity and wide acceptance in the market. Company A also stated that bast fibers could *easily be incorporated into tee-shirt production. This would be a good way to gauge consumer attractiveness to the materials.*

4.1.2 Company B analysis

Informal Conversational Interview Questions/answers:

1. **What information would you give to individuals (i.e. Companies, individuals, farmers, Designers, product developers, students) on the growth, processing, and use of bast fiber materials?**

Company B uses only hemp and some organic cotton in their products. Company B discussed the basics of growing hemp for product, and the legal, practical, and technical hurdles that must be taken into account when entering into this endeavor. Hemp is illegal to be grown under current federal restrictions within the United States of America, therefore making that the number one setback for those wanting to participate in this industry within the United States. If hemp is being grown in a foreign country, the farmer must choose which raw material they want to produce, seed or fiber. At farm level these are the only two options and the processing of the two are different. The more lucrative raw material however, is growing hemp for fiber. Currently the average for hemp fiber is $0.55 to $0.80 per pound, while seed can get $0.39-$0.60 per pound, and hurd only sells for about $0.15 to $0.30 per pound. The long fiber has the most uses and has the most value to the farmer.

2. What advantages/disadvantages are associated with using bast fibers in textile products

Company B provided some insight to using hemp and how it can not only make a product better for the environment but also can improve beneficial properties of products. Hemp fiber is one of the strongest most durable natural fibers. Its longer length and greater surface area contribute to a stronger yarn. Pure hemp yarns are stronger than flax and much stronger than cotton. Hemp also has one of the lowest percent elongations of any natural fiber which contributes to its ability to hold its shape. For this reason hemp is looked at as a strong contender for a more sustainable interior market, as hemp can be pulled taut around the furniture and remains firm throughout the life of the product. One disadvantage of flax as a textile is its inability to retain shape, and therefore causes 'puffy' elbows or knees when used in apparel, hemp, however, does not have this disadvantage.

2. **What part of the textile industry do you think bast fibers have the most potential to succeed?**

Company B sees the potential for hemp being more suitable for woven products and interior products, but can contribute certain properties to blended knits. Hemp has the best ratio of heat capacity compared to both flax and cotton, which keeps hemp warm in cold weather and cool in warm weather. This could be beneficial for performance wear such as sportswear or Performance undergarments (such as tee-shirts) and also for insulation products.

Company B is striving to push the market forward in the use of hemp textiles and other sustainable bast fibers. The company is a one of a kind company, without any one company being a direct competitor of theirs. They provide wholesale and retail sales of hemp fabrics and other products to companies who wish to grow their company towards being more sustainable.

4. Would your company be interested in helping out this research in any way? (i.e. possibly donating fabric yardage that you think would be a good comparison fabric for this research, specifically any that are bast fiber/blends)

Company B strives to push hemp as a potential mainstream fiber for the textiles industry, and was interested and willing to participate in the hand evaluation survey, discounting both a 100% hemp jersey knit (fabric B) as well as an organic cotton/hemp blend (fabric A). Company B states that there has been less research on consumer acceptance of bast fiber knits, and that this would be a good opportunity to rate the hand of the fabric. However, when used in woven interior products, the hand of the fabric has more leeway in the way of texture etc.

4.1.3 Company C analysis

Informal Conversational Interview Questions/answers:

1. **Does your company use any bast fibers or bast fiber blends in their Research and development or product development departments? If so what advantages/disadvantages have you found?**

Although they promote cotton, they have had interest in bast fibers and have done some inspiration development as well as other trials with hemp and linen as blending material for cotton. When working with bast/cotton blends for inspiration, Company C usually is trying to achieve a more natural or home spun look often associated with hemp or linen fabrics. The fabrics seem to have a rustic and/or vintage feeling about them. When using these fabrics as blends Company C has noted that the hand of the fabric is usually compromised, resulting in a more dry, raspy, or textured hand.

2. **Does your company do any form of hand evaluation testing for their fabrics that they use?**
If so, what types of questions are assessed/give the best results? What is the evaluation process?

Company C does conduct physical hand evaluation panels within their company. These are usually conducted as informal panels using people from within the company, specifically within the research and development team. For example, of one physical hand panels that were conducted tested different types of softeners on the same type of fabric. The fabrics were numbered 1-10, and participants were asked to rank the fabrics from best to worst. Company C has also conducted consumer hand panel. These are conducted with 20 participants who were selected using an outsourced survey company. These 20 participants are then blindfolded *and asked several questions regarding different types of fabrics, such as; what is the softest? What do you prefer? What do you think is the content of the Fabric? What type of Garment would this fabric be good for? Etc. These type of hand evaluation panels have been done with both knitted and woven fabrics, and tend to give the clearest personal, or consumer feedback.*

3. Do you see a potential for bast fibers in the apparel or interior industry? Where? Why or Why not?

There is always a place for linen in the market. I see it more as a seasonal fiber – a spring/summer fiber – as wool is a fall/winter. We try and make cotton season-less but traditionally you will find more cotton (in some product categories like dresses and pants) in the spring/summer market.

4. Would your company be interested in helping out this research in any way? (i.e. possibly donating fabric yardage that you think would be a good comparison fabric for this research, specifically any that are bast fiber blends or sustainable if applicable, otherwise, the most commonly used fabrics, i.e. cotton jersey knit tee-shirt type material).

Company C provided fabric D for the use in this research. Fabric D is 100% cotton knit that Company C felt would be a good comparative fabric for the hand evaluation. Company C stated that Fabric D had succeeded in the market and therefore would be a good fabric for the hand evaluation.

4.1.4 Overview of Results

As seen in Table 9, results from the company interviews showed that all three companies were working with bast fibers in their research and development. In addition, all three companies stated that there is a potential market acceptance for bast fibers.

Table 9: Summation table of Phase One results.

QUESTION	RESULTS			
	Company A	**Company B**	**Company C**	**Additional Comments**
Current use in company products?	No	Yes	N/A	
Current use in research and development?	Yes	Yes	Yes	All companies have / are researching potential use bast fibers.
Potential for market acceptance?	Yes	Yes	Yes	
Product category with most potential	Apparel	Interiors primarily (also apparel)	Home interiors	All companies expressed the opinions of definite potential in either market.
Does company Conduct physical hand evaluations of fabrics?	Informal	N/A	Informal	
Nomination of fabric type for Phase Two hand evaluation	Tee Shirt weight jersey knits	N/A	N/A	All three companies thought knits were more appropriate for hand evaluations.

Company C conducts research on market acceptance and product innovation but does not create the actual products for the market, hence the not applicable for the first question. Company C has experimented with both hemp and linen in their research and development departments. Company A is more invested in apparel, while Company B has interest in both the apparel and interior market and sells both woven and knit hemp fabrics. Company C has experimented with bast fibers in both woven and knit fabrics. Therefore their answers for potential market reflect their company products. Company A was interviewed first, and felt strongly that bast fibers had a high suitability for the knit tee shirt market. Company A also argued that because tee shirts are worn against the skin, a hand evaluation was an appropriate method of assessment. Company A also nominated the t-shirt as the end product because it is an internationally known product. This company aided the principal investigator in narrowing down questions for the purchasing decisions of the evaluators and sustainable apparel as well as donated knit material for the survey. Company B thought that bast fibers were better suited for the interior market because of its durability and low percent elongation (its ability to hold its shape) but thought that for the purpose of this survey it would be interesting to test knit fabrics because less research had been done in this area. Company C was willing to donate a cotton jersey knit which acted as a good comparison fabric.

4.2 Phase Two Results: Physical Fabric Hand Evaluation

4.2.1 Sample characteristics

The sample of participants for Phase Two included 103 subjects who reside in North Carolina and who attend a textiles university (students and faculty). There was one unusable subject because not all of the responses in the survey were recorded.

The potential amount of participants that were reached out to with email recruiting and class recruiting was 950 students making the overall response rate of this study approximately 10.84 percent. According to Porter and Umbach's (2006) research on student survey response rate across institutions, public universities in more urban cities such as the textiles university in which the research was conducted, will have a lower response rate than rural or private universities. Liberal arts universities have higher response rates as well as universities with fewer students. The lower response rate is also directly correlated with the time and location requirements for this study. The physical need to feel and respond to fabrics dictated that a central location be used for all participants. In addition, because participants had to adequately feel and then rate each fabric, the procedure could not be completed in less than 20 minutes. Studies have found that surveys administered by web or by mail are more likely to be completed at a higher response rate than surveys requesting subjects in a specific location (Umbach, 2006).

The respondents were composed of 79.6 percent female and 20.4 percent male. The male/female ratio of respondents corresponded with the textile university's male to female ratio. The total of undergraduate and graduate students in 2011 was 666 people in total in the Textiles and Apparel Technology Management department, 535 of them are female while 131 are male, that is approximately an 80.3 percent female to 19.6 percent male ratio (North Carolina State University Enrollment Report, 2011). Figure 13 shows a pie graph with the female to male ratio of respondents.

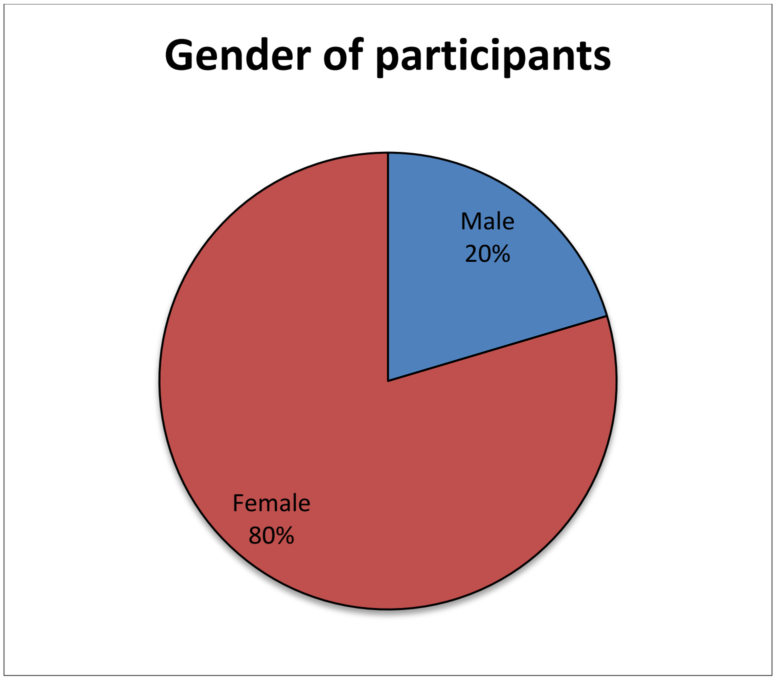

Figure 13: Male/Female Ratio of Survey Respondents

74.8 percent of respondents self-identified themselves as Caucasian, 15.5 percent of respondents identified themselves as Asian, 5.8 percent as African American, 3.9 percent as Hispanic, and 3.9 percent as other (which consisted of American Indian (or Native American), Anatolian, Arab American, or Two or more of the above mentioned) . This corresponds to the University department totals as follows; 73.6 percent Caucasian, 5.6 percent Asian (or Asian American), 9.8 percent African American, 2.5 percent Hispanic and 7.8 percent other (which includes International, Unknown, Native American, or Two or more of the above mentioned). Figure 14 demonstrates the breakdown of the ethnicity of the respondents.

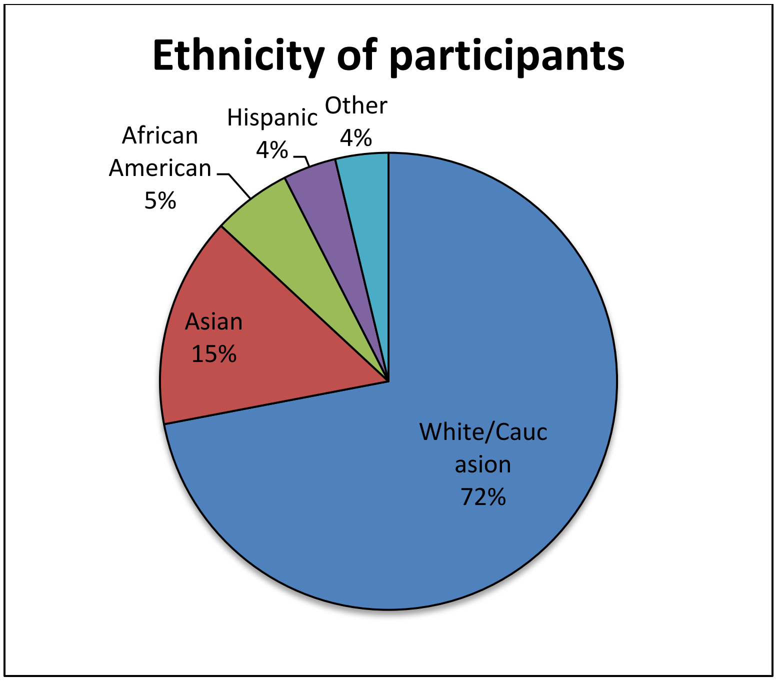

Figure 14: Ethnicity of Survey Respondents

The sample included subjects who ranged in age from 18 to 40, while the majority, 84 percent fell in the 18-25 age range.

4.2.2 Part I: Rating results

In order to evaluate consumer response and acceptance of bast fiber fabrics, subjects were asked to rate each of 5 fabrics for comfort/non-comfort, and seven additional attributes which included; cool/warm, dry/wet, smooth/rough, bald/hairy, thin/thick, flexible/stiff, and stretchy/non-stretchy. Each attribute was rated on a five point Likert Scale. To determine the attribute levels for each fabric, descriptive statistics of each attribute rating for each fabric was calculated for all subjects. Using statistical software SAS, T-tests were performed to determine if the difference between attribute ratings for each fabric type is statistically significantly different. These tests were also used to determine if any attributes have a significant relationship to determining the comfort level of the fabrics. The data was used to determine how the bast fiber fabrics rated in comparison to the non-bast fiber fabrics, and how the bast fiber fabrics rated among one another. Summary statistics were conducted to determine the mean, median and mode ratings of each fabric for each attribute. The data was also used to determine how the fabrics ranked for the product that was shown to each subject. A comparison analysis was conducted on all fabrics and attributes. All statistical tests were analyzed at a 95% confidence level, and a p-value of 0.05 or less was deemed significant. See Table 10 for how the attribute ratings were coded for the statistical analysis.

Table 10: Attribute ratings

Rating	1	2	3	4	5
Temp	Very cool	Somewhat cool	Neither cool nor warm	Somewhat warm	Very warm
Moisture	Very dry	Somewhat dry	Neither dry nor wet	Somewhat wet	Very wet
Texture	Very rough	Somewhat rough	Neither smooth nor rough	Somewhat smooth	Very smooth
Hairy	Very bald	Somewhat bald	Neither bald nor hairy	Somewhat hairy	Very hairy
Thickness	Very thin	Somewhat thin	Neither thin nor thick	Somewhat thick	Very thick
Flex	Very stiff	Somewhat stiff	Neither flexible nor stiff	Somewhat flexible	Very flexible
Stretch	Very non-stretchy	Somewhat non-stretchy	Neither non-stretchy nor stretchy	Somewhat Stretchy	Very stretchy
Comfort	Very uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Very comfortable

5.2.2.1 Attribute ratings of fabrics

Comfort

Participants were asked to rate the comfort of the five fabrics using a 5 point Likert scale with 1=Very Uncomfortable, 2=Somewhat Uncomfortable 3= Neither Comfortable nor Uncomfortable, 4= Somewhat Comfortable and 5=Very Comfortable.

The Fabric that rated the most comfortable based on mean was Fabric E, with a mean of 4.50, while Fabric A rated least comfortable, with a mean of 2.87.

The mean, median, and mode of all fabrics were as follows; the median comfort rating value for Fabric A is three while the mean falls just below at 2.87. The mode, for comfort of Fabric A is three, neither comfortable nor uncomfortable. The median comfort rating for Fabric B was four, while the mean was rated at 3.58. The mode for Fabric B was four, somewhat comfortable. Fabric C's median was four, while the mean was rated at 3.63. The mode for Fabric C was four, somewhat comfortable. Fabric D's median was 4 while the mean was 4.14. The mode for Fabric D was four, somewhat comfortable. Fabric E's median was 5, and comfort mean coming in at the highest rating was 4.50. The mode for Fabric E was 5, very comfortable. Please refer to tables 16 through 20 for all of the means medians and modes of the fabrics for each attribute. When comparing bast fiber fabrics against non-bast fiber fabrics (Fabric A is eliminated because it is a blend), there is a significant difference between bast (B and C) and non-bast fabrics(D and E). The bast fiber fabrics (B and C) have a comfort mean of 3.6, while the non-bast Fabrics (D and E) has a mean of 4.3. The two bast fiber fabrics (B and C) when rated against each-other did not have a significant difference (p-value > 0.05) when comparing their comfort level. Non-bast fabrics (D and E), although not being looked at specifically for this research, only as a comparison to the bast, did have a significant difference in comfort compared to one another. Fabric E, the non-bast, sustainable fabric, rated highest in comfort among all of the fabrics.

Cool/warm

Participants were asked to rate the temperature of the five fabrics using a 5 point Likert scale with 1=Very Cool, 2=Somewhat Cool 3= Neither Cool nor Warm, 4= Somewhat Warm and 5=Very Warm. The Fabric that rated the coolest based on mean was Fabric B, with a mean of 2.09, while Fabric A rated the warmest, with a mean of 2.98.

The mean, median, and mode of all fabrics were as follows; fabric A's median rating of temperature was three, and a mean of 2.98. The mode of Fabric A was two, somewhat cool. Fabric B had a median temperature rating of two, and a mean of 2.09.The mode of Fabric B was Two, somewhat cool. Fabric C had a median temperature rating of two, and a mean of 2.12. The mode of Fabric C was two, somewhat cool. Fabric D's median temperature rating was three, and the mean was 2.91. The mode of Fabric D was two, somewhat cool. Fabric E had a temperature median of three and a mean of 2.76. The mode of Fabric E was two, somewhat cool. Temperature was not deemed to have a significant relationship to comfort overall for all fabrics, although Fabric D did have a significant correlation between temperature and comfort. The bast fiber fabrics vs. the non bast fabrics did have a significant difference in temperature ratings. Bast fiber fabrics (B and C) had a combined mean of 2.11, while non-bast fiber fabrics (D and E) had a combined mean of 2.83. There was no statistical significance when comparing only bast fibers or only non-bast fibers.

Wet/Dry

Participants were asked to rate the moisture content of the five fabrics using a 5 point Likert scale with 1=Very Dry, 2=Somewhat Dry 3= Neither Dry nor Wet, 4= Somewhat Wet and 5=Very Wet.

The Fabric that rated the driest based on mean was Fabric A, with a mean of 1.96, while Fabric B rated the wettest, with a mean of 2.57.

The mean, median, and mode of all fabrics were as follows; all of the fabrics had moisture rating medians of two. Fabric A had a mean of 1.96, and a mode of two. Fabric B had a mean of 2.57, and a mode of two. Fabric C had a mean of 2.46, and a mode of two. Fabric D had a mean of 2.34 and a mode of two. Fabric E had a mean of 2.76 and a mode of two. Overall, for all of the fabrics, there was not a significant correlation between moisture and comfort. Moisture did have a significant relationship to comfort for Fabric A, demonstrating that there was a positive correlation between evaluators more commonly stated that the fabric was dry and uncomfortable.

When rating the wetness/dryness of bast fiber fabrics compared to non-bast fiber fabrics, no significant difference was found. No significance was found when comparing only bast fiber fabrics to each other nor was there significance between the non-bast fiber fabrics.

Smooth/Rough

Participants were asked to rate the texture of the five fabrics using a 5 point Likert scale with 1=Very Rough, 2=Somewhat Rough 3= Neither Rough nor Smooth, 4= Somewhat Smooth and 5=Very Smooth. The Fabric that rated the smoothest based on mean was Fabric E, with a mean of 4.13, while Fabric A rated the roughest, with a mean of 2.25.

The mean, median, and mode of all fabrics were as follows; the median texture rating for Fabric A fell at two, while the mean was 2.26. The mode for Fabric A was two, somewhat rough. Fabric B's texture median was three, and the mean was 3.12. The mode for Fabric B was four, somewhat smooth. Fabric C's texture median was two, while the mean was 2.75. The mode for Fabric C was two, somewhat rough. Fabric D's texture median was four, and its mean was 4.11. The mode for Fabric D was four, somewhat smooth. Fabric E's median was four, and its mean 4.13. The mode for Fabric E was four, somewhat smooth. Overall there is a significant correlation between texture and comfort, meaning that the more smooth a fabric is rated, and it is also rated more comfortable. There is also a significant difference between bast and non-bast fiber fabrics. Bast fiber fabrics have a combined mean of 2.93, while non-bast fabrics have a combined mean of 4.11. When the bast fiber fabrics were compared against one another, there was a significant difference between them, being that the mean for Fabric B was 3.12, and the mean for Fabric C was 2.75. Fabric D and E were not significantly different.

Bald/Hairy

Participants were asked to rate the hairiness of the five fabrics using a 5 point Likert scale with 1=Very Bald, 2=Somewhat Bald 3= Neither Bald nor Hairy, 4= Somewhat Hairy and 5=Very Hairy.

The Fabric that rated the hairiest based on mean was Fabric A, with a mean of 3.03, while Fabric B rated the least hairy, with a mean of 2.98.

The mean, median, and mode of all fabrics were as follows; the median hairiness rating for Fabric A was three, and its mean was 3.03. The mode for Fabric A was three, neither hairy nor bald. For Fabric B, its median rating was two, and its mean was 2.49. The mode for Fabric b was two, somewhat bald. Fabric C had a median rating of three, and its mean was 2.86. The mode for Fabric C was three, neither hairy nor bald. Fabric D's median for hairiness fell at three, while its mean was at 2.74. The mode for Fabric D was two, neither hairy nor bald. Fabric E had a median of three, and a mean of 2.84. The mode for Fabric E was three, neither hairy nor bald. There was not a significant correlation between hairiness/baldness and comfort overall. There is no significance between the comparison of hairiness level when comparing the bast and non bast fabrics. There is significance when comparing the two bast fiber fabrics against each other, where B had a mean of 2.16, and C has a mean of 1.53.

Thin/Thick

Participants were asked to rate the temperature of the five fabrics using a 5 point Likert scale with 1=Very Thin, 2=Somewhat Thin 3= Neither Thin nor Thick, 4= Somewhat Thick and 5=Very Thick.

The Fabric that rated the thinnest based on mean was Fabric C, with a mean of 1.53, while Fabric A rated the thickest, with a mean of 3.12.

The mean, median, and mode of all fabrics were as follows; the rating for Fabric A's thickness median is three, while it's mean was 3.12. The mode for Fabric A was three, neither thick nor thin. Fabric B has a thickness median of two, and its mean was

2.16. The mode for Fabric B was two, somewhat thin. Fabric C has a median of one, while it's mean was 1.53. The mode of Fabric C was one, very thin. Fabric D had a thickness median of three, and its mean was 2.74. The mode for Fabric D was two somewhat thin. Fabric E had a median of two, and its mean was 2.40. The mode for Fabric E was two, somewhat thin. There is not an overall significant correlation between thickness and comfort, although Fabric B and D both have significant correlations between comfort ratings and thickness ratings. When comparing the bast and non-bast fibers there is a significant difference between bast and non-bast, as bast fiber fabrics have the combined mean of 1.84 and non-bast fibers are rated slightly thicker at the combined mean of 2.57. The bast fiber fabrics also have a significant difference when rated against each other, as Fabric B has a mean of 2.16 and Fabric C has a mean of 1.53. Fabrics D and E also have a significant difference while Fabric D has a mean of 2.74 and Fabric E has a mean of 2.40.

Flexible/ Stiff

Participants were asked to rate the flexibility of the five fabrics using a 5 point Likert scale with 1=Very Stiff, 2=Somewhat Stiff 3= Neither Stiff nor Flexible, 4= Somewhat Flexible and 5=Very Flexible

The Fabrics that rated the most flexible based on mean was both Fabric C and Fabric E, with a mean of 4.43, while Fabric A rated the least flexible, with a mean of 3.63. The mean, median, and mode of all fabrics were as follows; Fabric A had a median of four, and a mean of 3.63. The mode for Fabric A was four, somewhat flexible. Fabric B had a median of four, and a mean of 4. 13. The mode of Fabric B was four, somewhat flexible. Fabric C has a median of four and a mean of 4.43. The mode of Fabric C was five, very flexible. Fabric D has a median of four, and a mean of 4.13. The mode of Fabric D was four, somewhat flexible. Fabric E has a median of four and a mean of 4.43. The mode of Fabric E was four, somewhat Flexible. The comparison between bast fiber fabrics and non-bast fiber fabrics is not significant. Bast fiber Fabrics B and C do have a significant difference as B has a mean of 4.13 and C has a mean of 4.43. Non-bast fiber Fabric D and E are also significantly different according to the T tests, as D has a mean of 4.02, and E has a mean of 4.43. Flexibility is a significant attribute that relates to rating comfort.

Stretch/Non-stretch

Participants were asked to rate the stretchiness of the five fabrics using a 5 point Likert scale with 1=Very Non-stretchy, 2=Somewhat Non-stretchy 3= Neither Non-stretchy nor Stretchy, 4= Somewhat Stretchy and 5=Very Stretchy.

The Fabric that rated the most stretchy based on mean was Fabric E, with a mean of 4.42, while Fabric A rated the least stretchy, with a mean of 3.24.

The mean, median, and mode of all fabrics were as follows; all of the fabrics had their median ratings at four. Fabric A had a mean of 3.24, and a mode of four, somewhat stretchy. Fabric B had a mean of 3.26, and a mode of four, somewhat stretchy. Fabric C had a mean of 3.89, and a mode of four, somewhat stretchy. Fabric D had a mean of 3.57, and a mode of four, somewhat stretchy. Fabric E had a mean of 4.42 and a mode of five, very stretchy. When comparing bast fiber fabrics with non-bast fiber fabrics, there was found to be a significant difference. Bast fabric had a combined mean of 3.60 while non-bast had a mean of 4.32. The two bast fiber fabrics were not found to be significantly different when compared. The non-bast fabrics were significantly different however, where D had a mean of 4.15 and E had a mean of 4.5. The T-tests showed that stretch was not an overall significant factor to relate to comfort, although Fabric A had a significant correlation between stretch and comfort as well as Fabric B.

The following tables (11-15) show the summary statistics (mean, median and Mode) for all of the fabrics as they rated for each of the seven attributes, and how they rated for overall comfort.

Table 11: Summary statistics for Fabric A

Variable	Mean	Median	Mode
temp	2.9803922	3.0000000	2.0000000
moisture	1.9607843	2.0000000	2.0000000
texture	2.2549020	2.0000000	2.0000000
hairy	3.0294118	3.0000000	3.0000000
thickness	3.1176471	3.0000000	3.0000000
flex	3.6274510	4.0000000	4.0000000
stretch	3.2352941	4.0000000	4.0000000
comfort	2.8725490	3.0000000	3.0000000

Table 12: Summary statistics for Fabric B

Variable	Mean	Median	Mode
temp	2.0882353	2.0000000	2.0000000
moisture	2.5686275	2.0000000	2.0000000
texture	3.1176471	3.0000000	4.0000000
hairy	2.4901961	2.0000000	2.0000000
thickness	2.1568627	2.0000000	2.0000000
flex	4.1274510	4.0000000	4.0000000
stretch	3.2647059	4.0000000	4.0000000
comfort	3.5784314	4.0000000	4.0000000

Table 13: Summary statistics for Fabric C

Variable	Mean	Median	Mode
temp	2.1274510	2.0000000	2.0000000
moisture	2.4607843	2.0000000	2.0000000
texture	2.7450980	2.0000000	2.0000000
hairy	2.8627451	3.0000000	3.0000000
thickness	1.5294118	1.0000000	1.0000000
flex	4.4313725	4.0000000	5.0000000
stretch	3.8921569	4.0000000	4.0000000
comfort	3.6274510	4.0000000	4.0000000

Table 14: Summary statistics for Fabric D

Variable	Mean	Median	Mode
temp	2.9117647	3.0000000	2.0000000
moisture	2.3431373	2.0000000	2.0000000
texture	4.1078431	4.0000000	4.0000000
hairy	2.7352941	3.0000000	2.0000000
thickness	2.7352941	3.0000000	2.0000000
flex	4.0294118	4.0000000	4.0000000
stretch	3.5686275	4.0000000	4.0000000
comfort	4.1470588	4.0000000	4.0000000

Table 15: Summary statistics for Fabric E

Variable	Mean	Median	Mode
temp	2.7647059	3.0000000	2.0000000
moisture	2.4313725	2.0000000	2.0000000
texture	4.1274510	4.0000000	4.0000000
hairy	2.8431373	3.0000000	3.0000000
thickness	2.4019608	2.0000000	2.0000000
flex	4.4313725	4.0000000	4.0000000
stretch	4.4215686	5.0000000	5.0000000
comfort	4.5000000	5.0000000	5.0000000

For all statistical information on the attributes, relationships between attributes and summary statistics see APPENDIX H.

4.2.3 Part II: ranking results

Part Two of the survey asked participants to rank the five fabrics in order from most desirable to least desirable for use in a tee shirt (as seen in Figure 18). Overall Fabric E, organic cotton/recycled polyester blend was the fabric that was most often placed in the most desirable location, while Fabric A, organic cotton/hemp blend was most often placed in the most desirable position. The Figures below (Figures 15-19) show the percentages that each fabric was ranked from most desirable (one) to least desirable (five).

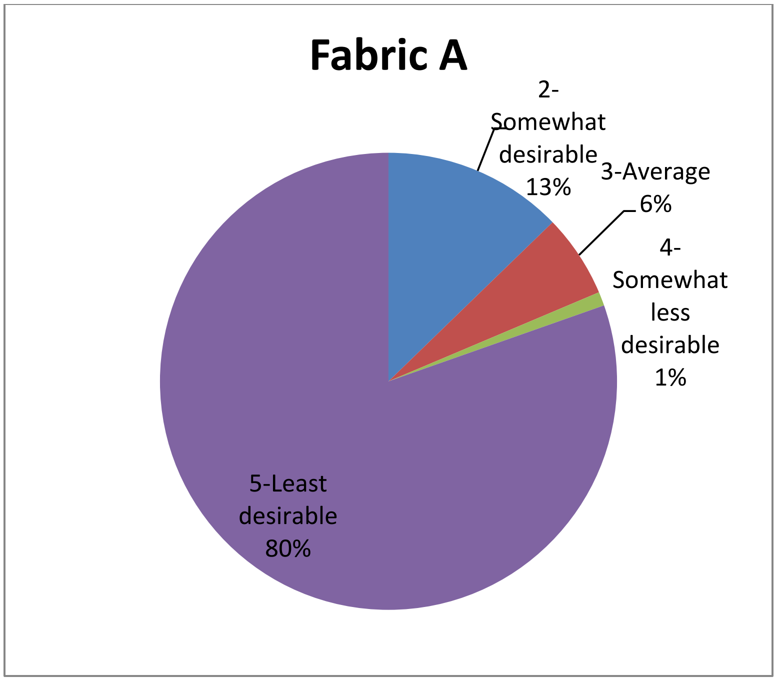

Figure 15: Rank percentages of Fabric A

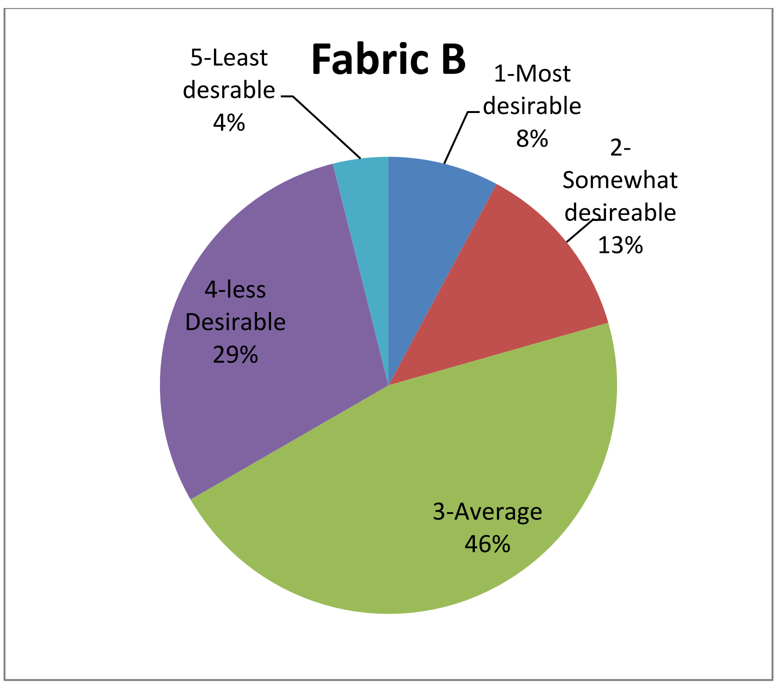

Figure 16: Rank percentages for Fabric B

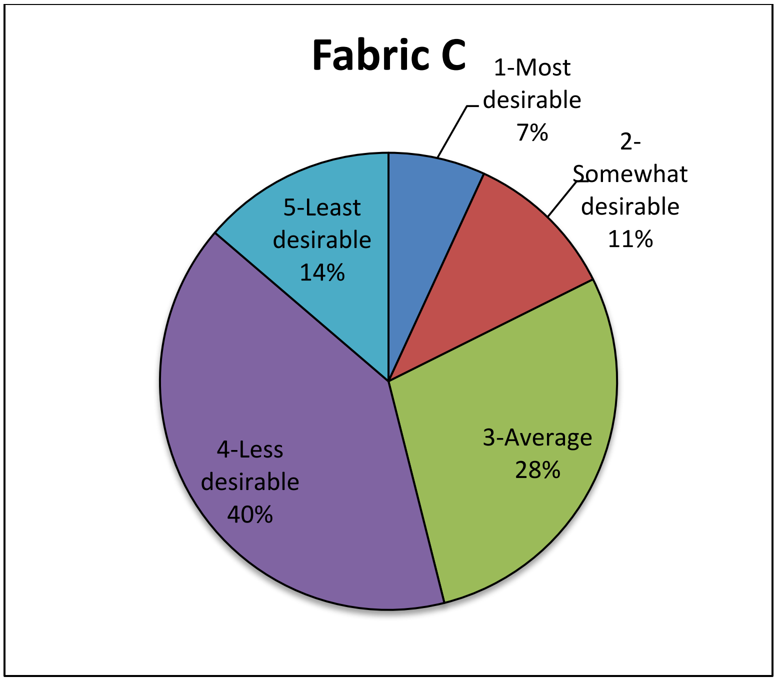

Figure 17: Rank percentages for Fabric C

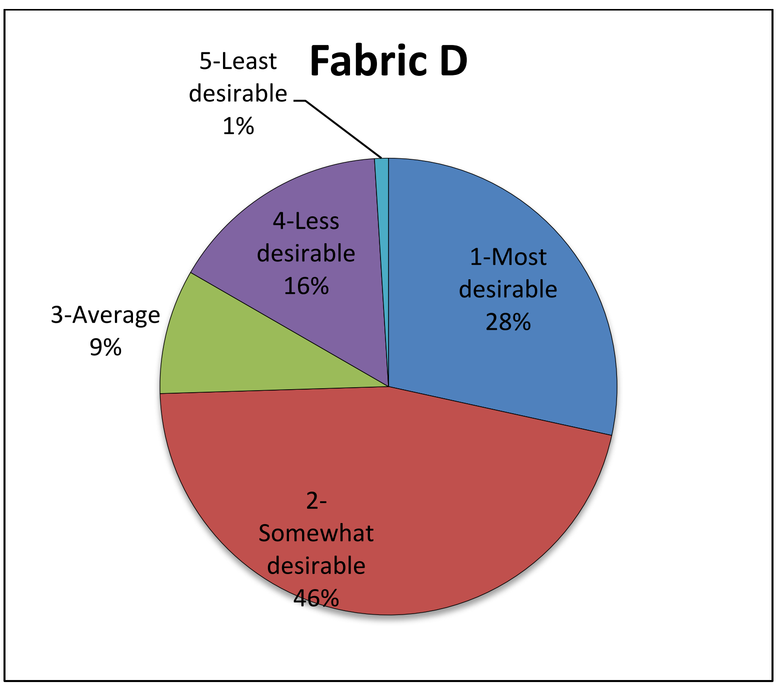

Figure 18: Rank percentages for Fabric D

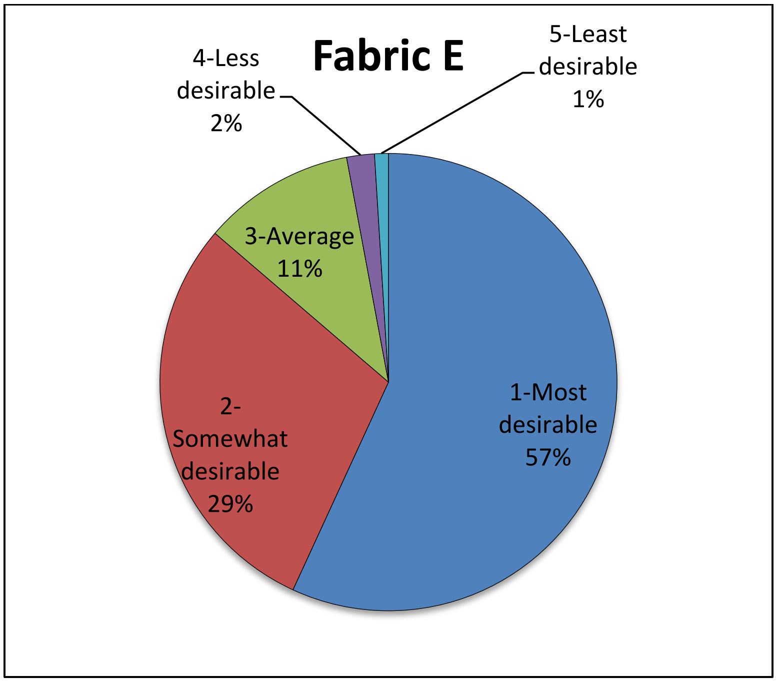

Figure 19: Rank percentages for Fabric E

Figure 20 shows the amount of times each fabric was placed in each location (one through five, one standing for most desirable for the product, and five standing for least desirable for the product).

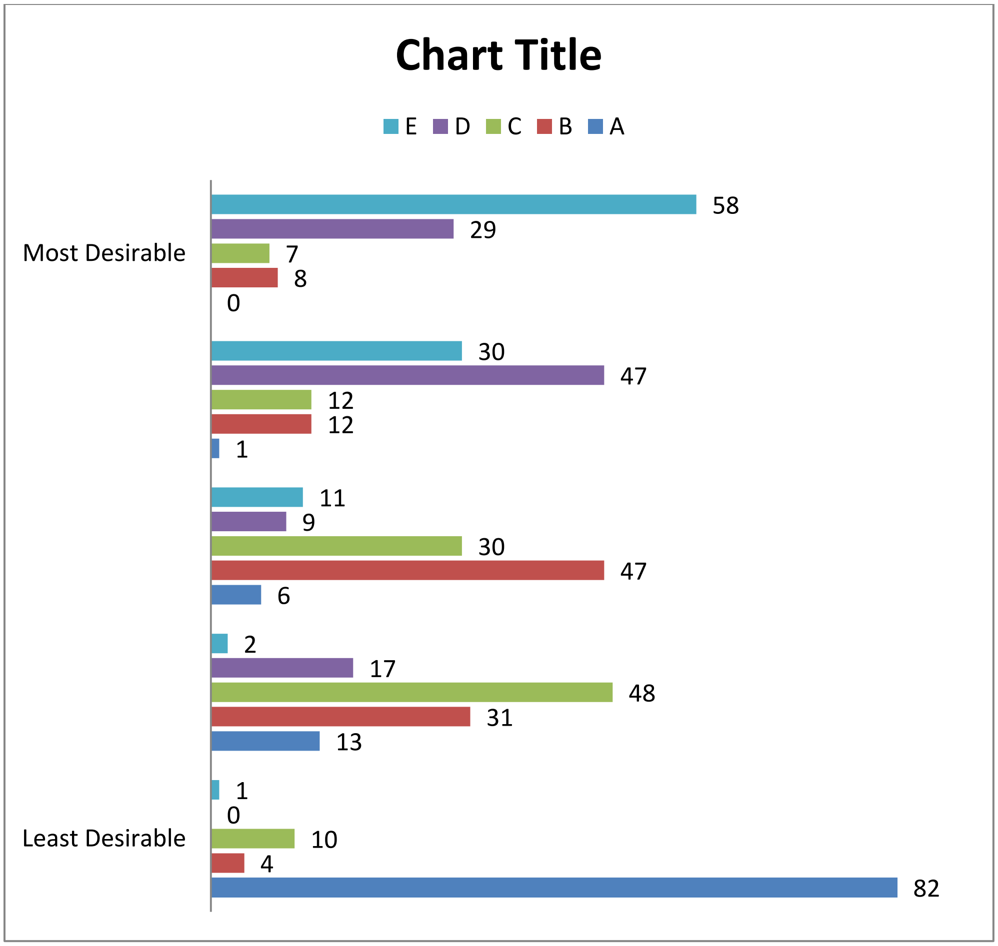

Figure 20: Participant rank frequency (mode) of Fabrics A through E

Although Fabric A rated among the bottom fabrics, this may be due to the thickness and lack of finish that is present. Many participants added in their comments that this would be a fabric that may be better used for interiors of more heavy weight apparel. Many people stated it to be more beneficial for sportswear, lightweight sweaters or sweatshirts, and bottom weight casual wear. Many participants also commented on this fabric as a heavier weight fabric that would be better suited for colder weather. Fabric A did have some unevenness, and was rated among the top fabrics for texture (rough). It is interesting to note that this blend (cotton and hemp) was rated lower than the 100% hemp fabric, and the 100% cotton fabric, therefore the conclusion cannot be drawn that this fabric was rated lowest because of the hemp fiber. This could be due to several factors including lack of finish, quality of the blend, weight of the fabric, or quality of fibers used.

4.2.4 Phase Two: data analysis/summary

Comfort

Although Fabric E was rated the highest in comfort, Fabrics C and B were still rated above the neutral (neither comfortable nor uncomfortable) rating so it can be taken into account that they were still considered comfortable. Fabrics B, C, and D all had a mode of somewhat comfortable. The comments on all of these fabrics were more positive than negative denoting that any of these fabrics would be suitable, or comfortable for wear. Many of the evaluators commented that the fabrics were all similar in comfort and had only slight changes in weight, texture, and drape. Many comments denoted the Fabrics C and B as not suitable for apparel because they felt too thin or sheer, to be worn in public, unless the individual had an undergarment on for cover. This is however a judgment of touch alone and evaluators couldn't actually see the cover of the fabric. Fabric A was signified as being too thick and warm for comfortable wear, which also correlated with being less flexible and more suitable for the interior industry.

Comments were given about the comfort of the fabrics as well. Fabric A had many comments that varied from aspects about the texture and weight of the fabrics to the comfort and application of the fabric. Several examples that show the spectrum of comments given include;

"Not as soft as other fabrics, but still desirable"

"Fabric is noticeably rougher and thicker than the other fabrics. Also heavier"

"Feels like a fabric more suitable for home goods"

"Textured and nubby"

"The fabric is comfortable, but not particularly for a t-shirt"

"Feels like a winter fabric" –Anonymous evaluators

These comments most commonly mentioned aspects of the texture of the fabric and the weight (being heavier) which could have a correlation to how the fabric was rated on the Likert scale for comfort. Texture had a significant correlation with comfort with a p value of 0.0007, and thickness and comfort had a close to significant correlation with a p-value equaling just above 0.05, at 0.06. Fabric A's mean deemed it somewhat uncomfortable, at 2.87.

Fabric B had an array of comments from the evaluators most commonly stating the fabric was comfortable, cool, and light weight. Several of them mentioned there was a texture to the fabrics as well. Some examples of comments were;

"The fabric was really nice to the touch"

"Cool to the touch, smooth, but not soft"

"This fabric seems a little grainy but it still seems comfortable and soft"

"Feels luxurious"

The majority of the comments about the comfort of this fabric were positive, relating it to good drape, and lightweight feel. The mean for Fabric B was 3.58, meaning it was deemed somewhat comfortable. If weighing in on the comments mentioned about Fabric B, it seems that this would be an accepted fabric in the market in the appropriate application.

Fabric C also had many positive comments, but some negative comments, denoting the fabric being very lightweight, or sheer. Many evaluators' comments denoted that a fabric of this sheerness would not be appropriate to wear in a garment, while others commented on its comfort and drape. There were several comments mentioning slubs or uneven surface texture, while a few of them said this could cause discomfort, the majority of these comments were followed by stating, that these aspects of unevenness would not affect the comfort of wearing this shirt. Some of the comments were as follows;

"It's very thin. I feel like someone would be able to see through it"

"A little rough, but I like the drape and coolness"

"I would say this would be a comfortable t-shirt, but might be too thin."

"This does not feel like the fabric of any clothing article I own. It reminds me of a fabric in a shirt/blouse that a woman would wear when she is going out."

"Feels like fabric has slubs or is a burnout material" *-Anonymous evaluators*

Fabric D had mostly positive comments about hand, softness, comfort, and warmth. There were several comments denoting its feeling as inexpensive or cheap. The range is shown below with several comments;

"The fabric is very enjoyable to the touch"

"I think the yarn is not of high quality; but the finishing is good"

"I like this fabric, it's not too smooth or rough, and it's not too stretchy where I would worry about the garment deforming" *-Anonymous evaluators*

Most of the comments on this fabric seemed to parallel with how this fabric rated statistically, mostly denoting that it had soft feel and comfortable touch. Some of the comments about this fabric referred to the lack of stretch in one direction, stating that it may get stretched out or deformed and not have a significant amount of recovery, after time.

Fabric E had all positive comments noting that it was soft to the touch, appropriate for against the skin wear, and comfortable. Several comments addressed the stretch of the fabric and the smoothness as positive properties of the comfort of this fabric.

Several comments were;

"Feels like it was meant to be worn as a first layer, close to the skin"

" Very thin fabric with some properties of Lycra or spandex"

"Would be nice to wear, maybe a little rough" *-Anonymous evaluators*

This fabric was mostly described with positive comments.

Overall the ratings show that Fabric E was the most accepted for apparel and next to skin garments. Fabric D came in second in the comfort rating. It must be taken into account that both of these fabrics had a softener applied to the fabric during manufacturing and that could be a significant variable that aided in the comfort of these two fabrics. The other three fabrics had no softeners applied. Fabric B came in close behind at third. Fabric C was rated forth and Fabric A was rated somewhat uncomfortable.

It is important to mention, all fabrics, excluding A, rated above the neutral rating of neither comfortable nor uncomfortable, signifying they are all considered between somewhat comfortable and very comfortable.

Cool/Warm

Overall Fabric A was rated the warmest fabric out of the five fabric samples, the mean was rated at 2.98. There is a significant correlation between thickness and temperature for all fabrics, meaning the thinner they were rated, the cooler they were rated. Although Fabric A was rated the thickest and warmest, it is actually lighter than Fabric B (A= 6.5 oz. /yd^2 and B=6.8oz/yd^2). Many of the comments about the warmth of Fabric A signified that the fabric was initially cool to the touch, but warmed up significantly with contact. This could be a result of the insulating properties of hemp which are noted to be considerably better than other non bast natural fibers (Frank, 2000). Several of the comments are listed below;

"Started cool and then warmed up as I handled the fabric"

"Medium weight, feels like it would keep you in the middle you wouldn't be too hot or too cold."

"Probably insulates well, but surface felt cool to touch." –Anonymous evaluators

Fabric D came in close behind with a mean of 2.91 which statistics show is significantly related to the hairiness rating as well as the thickness (see APPENDIX H for full statistical relationships of attributes). The evaluators' comments on this fabric stated that it didn't warm up with increased contact but felt warm to the initial touch, and therefore would be a successful as a garment to wear in cooler weather.

Wet/Dry

Overall, based on mean Fabric A was rated the driest fabric and Fabric B was rated the wettest. According to the analysis of the comments, the question of moisture was among the most difficult to understand, and evaluators either answered based on the ability of that fabric to absorb moisture, or the actual feeling of moistness in the fabric. Many comments indicated that unless there was actually moisture dripping off of the fabric, evaluators would rate the fabric as dry. Some of the comments for the moisture of the fabrics included;

"[Fabric A] seems like it would hold a lot of moisture"

"[Fabric B] feels cool without feeling wet"

"[Fabric E] feels like it would be very absorbent but not dry quickly"

The mean, median, and mode of the ratings of all fabrics demonstrate that most evaluators identified the fabrics to be somewhat dry. Only in Fabric A did moisture have a significant correlation with texture.

Smooth/Rough

Overall Fabric E was rated to be the smoothest with a mean of 4.13, Fabric D came in second at 4.10, and Fabric B came in close behind with a 3.11. This mean designates Fabric B as being rated smooth. Fabric B is the smoothest out of all bast fiber fabrics and blends. Fabric A Cotton/bast blend, came in as the most rough, which could signify that this is a bad example of this type of blend since both of the pure forms of these fibers rated smooth while the blend rated rough.

Many of the ratings designated Fabric C as somewhat rough, but the participants' comments suggest that although Fabric C had a texture it was still a smooth structure and was would still be smooth enough to wear. Many participants said that the reason for choosing rough was related only to the unevenness of the fabric and not to the actual roughness. When looking at these comments it is clear that the majority of the evaluators did enjoy this fabric and the texture that it had.

Some Comments on Fabric C included;

"Few rough places, other than that mostly smooth"

"It has average hand, not too smooth but not too rough. It kind of feels like I has a pattern on one side or that it is a ribbed fabric"

"Its soft but has texture to it"

The texture rating was significantly correlated with comfort in all fabrics, therefore designating it as a high contender to demonstrating comfort. Figure 21 shows the shows their relationship and how smooth/rough the fabrics were rated.

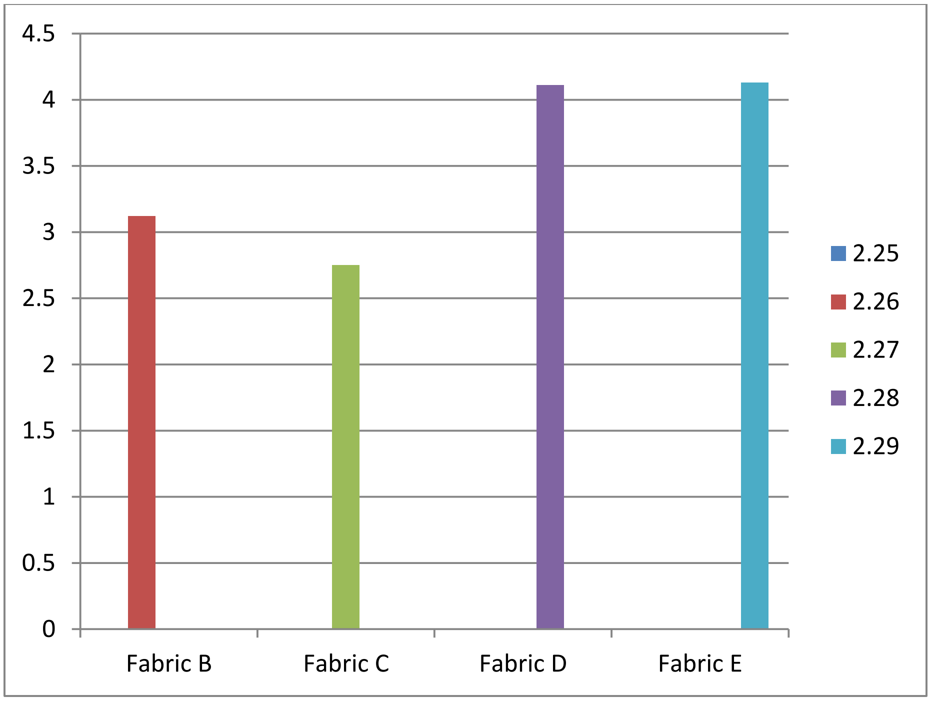

Figure 21: Texture mean ratings of fabrics

Although texture is rated as one of the most significant attributes related to comfort, according to the comments, Fabrics B and C both had unevenness that related to the rating of more rough, but not necessarily uncomfortable.

Bald/Hairy

Overall the hairiness ratings of the fabrics fell close to neither hairy nor bald. All of the Fabrics received a high frequency of ratings at the neutral rating scale. Fabric A had the highest hairiness rating, with a mean of 3.03, still falling at neither hairy nor bald. All of the fabrics were of jersey knit construction and didn't have many, if any, protruding fibers but they were natural fibers so they did not have as smooth a feeling of a continuous fiber such as polyester or silk. Many of the comments stated that the fabrics were not hairy, but still soft across all fabrics. Fabric A's comments signified that may of the evaluators may have rated it slightly more hairy than the others based on the presence of texture and thickness.

Thin/Thick

Overall Fabric A was rated the thickest and Fabric C was rated the thinnest. This rating significantly correlated with temperature, texture, flexibility, stretch and comfort with Fabric A (see APPENDIX H). Fabric B had a significant correlation between thickness and temperature, hairiness, and comfort. The comfort relation was a negative correlation, stating that the thinner the fabric the less comfortable it was rated. This is an interesting aspect to look at and to take into account, that maybe if people felt heavier weights of this fabric they would have rated it higher on the comfort scale. It is evident that the bast fiber fabrics have slightly less cover than the cotton or cotton blend fabrics according to the results. This may indicate that these fibers would be better suited for warmer seasons or could be made at a heavier density to provide for that extra cover.

Many of the comments indicated that Fabric A was too thick for a tee shirt but thinner than a heavy sweater. Most comments described it as a medium weight fabric. The comments on Fabric B indicated that because it was smoother and cooler this made the fabric feel thinner. Many comments also stated that although the fabric felt thin there was still enough cover to it, and still felt that it would hold up to wear and tear.

Fabric C, the thinnest of all the fabrics had many comments stating that its thinness would be to revealing in an apparel application. This could indicate that a heavier weight construction of these fabrics may have different results in all categories. According to the comments it seems that the weight of the fabric is a personal preference while some evaluators stated that thin and drapery fabric was preferred for a more luxurious and flattering fit, while others stated that their comfort level with the thin fabric was the issue. Fabric B and C were also compared to burnout fabric or vintage style tee shirts that are very popular in retail currently. Fabric D and E were both rated to be somewhat thin. Comparing all the fabrics means, there was only a range of 0.80, so the fabrics were relatively similar which correlates with the small range in technical weigh of the fabrics.

Flexible/Stiff

Overall the fabrics were all rated similarly for flexibility. The majority of evaluators chose four, somewhat flexible, for all fabrics. Fabric A received the least flexible score. There was a significant relationship between flexibility and thickness for Fabric A. All of the fabrics again were rated closely, mostly all of them falling somewhere between somewhat flexible and very flexible. Figure 22 shows their relationship and how flexible the fabrics were rated.

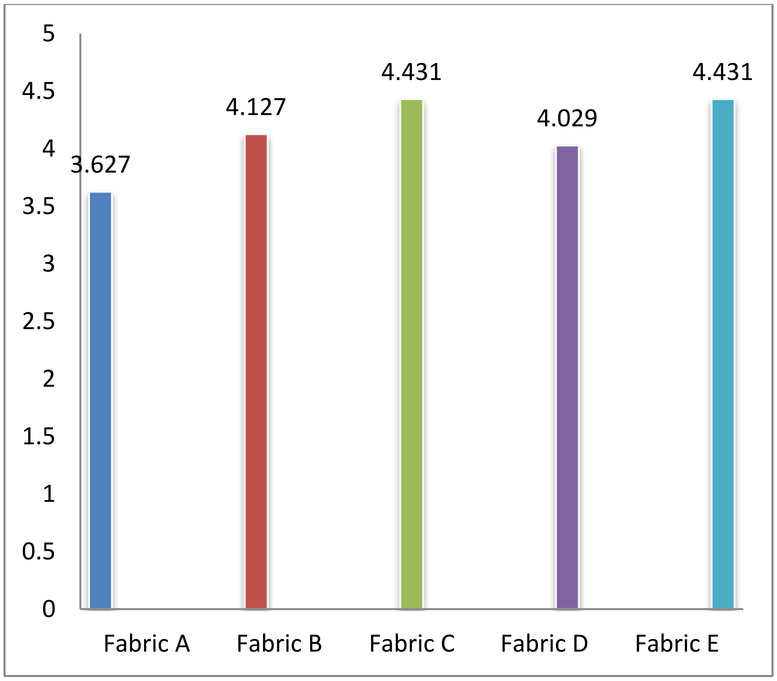

Figure 22: Flexibility mean ratings of fabrics

As you can see by the depiction of this graph, the range of flexibility is very low. Flexibility is one of the most significant ratings that determine comfort according to the results in this study, therefore, if flexibility is taken into account for comfort it seems that Fabrics E, B, and C would be rated highest in this category, all of which are sustainable fabrics, two of which contain bast fibers.

Stretch/Non-stretch

Overall, Fabric E rated most stretchy out of all the fabrics. This had a significant correlation between flexibility and comfort for this fabric (see APPENDIX H for correlation tables). The other fabrics all rated similar, while all of them had a mode of 4, somewhat stretchy. Their means fell between 3.24 (Fabric A) to 3.5 (Fabric D). As shown, all of the fabrics were averaged to be somewhat stretchy. When looking at the frequency of ratings, there was a very small amount of evaluators who chose the neutral (neither stretchy nor non-stretchy) option. Fabrics A, B, and C had significant correlation between stretch and comfort.

Product Types

Within the survey instrument, there was one open-ended question asking the evaluators to state what type of product they felt would be more suitable for each of the five fabrics.

Table 16 lists the product types mentioned by the evaluators being the most suitable for each of the five fabrics. Fabric D was rated highest for a tee shirt, with 57 votes, while Fabric E was rated the 2nd highest for a tee shirt with 55 votes. Fabric B had 36 votes for a tee shirt product, and Fabric C had 30 votes. Fabric A was rated lowest for a tee shirt end product with 13 votes, but was rated highest in home furnishings (22 votes) and outerwear (22 votes). Fabric A also was rated best for bottoms (17 votes) and sportswear (17 votes). It should be noted that fabric C was rated highest among undergarments as an end product, 9 evaluators voted it as a good fabric for close to skin garments.   Fabric D had a high rating for bedding (19 votes), Fabric E, B and C all had relatively high response rates as well for bedding (10 for Fabric E, 10 for Fabric B, and 9 for Fabric C) which also says that they would be for close to skin contact products. These responses imply that these fabrics are all comfortable fabrics, because it is highly necessary for bedding to be comfortable.

Fabric E and D had the highest rating for pajamas, which means they are both accepted as close to skin garments, while Fabric B and C also had relatively high response rates for this as well, although significantly less the Fabric D and E. It is interesting to note that Fabric B rated among the top (28 votes) for tops (non-tee shirt) and Fabric C came in second with 26 votes, which could imply that these fabrics are more applicable for higher end blouses, and fashion tops. These two fabrics were also rated best for dresses which are another typically higher priced item. This response rate could signify that the market for bast fiber fabrics may be more fashionable, less casual garments and garments where more drape is necessary. Fabric C was rated highest for accessories, particularly as an excellent scarf, which implies good drape, and possibly high quality. Table 16 displays a breakdown of the product types chosen for each fabric.

Table 16: Product types and applicable fabrics

Product Type	Fabric				
	Fabric A	**Fabric B**	**Fabric C**	**Fabric D**	**Fabric E**
Tee shirt	13	36	30	57	55
Tops	11	28	26	23	23
Bottoms	17	12	4	9	7
Dress	4	13	12	9	9
Outerwear	22	13	6	11	6
Sportswear	17	15	5	16	14
Pajamas	1	10	9	19	25
Undergarments	1	4	9	7	7
Accessories	9	8	20	6	8
Kitchen Textiles	7	9	3	1	0
Home furnishings	22	8	7	1	2
Bedding	7	10	9	19	10
Other	3	6	13	7	9

Product types were categorized by the principal investigator by analyzing all responses given by the evaluators and categorizing the broader themes that most often appeared. Table 17 exhibits the breakdown of the categories and what was included in each.

Table 17: Break down of broad categories

Category	Sub Category Inclusions
Tee shirt	Tee shirt
Tops	Polo shirt, blouse, woman's tops, shirts, fashion tops
Bottoms	Dress pant, trousers, skirt, shorts, pants, workpants,
Dress	Dress, gown
Outerwear	Cardigan, light sweater, outerwear, light jacket, suit jackets, structured outerwear, spring sweaters
Sportswear	Yoga Pants, workout gear, sweatpants, sweatshirt, exercise clothes
Pajamas	Travel apparel, pajamas, lounge wear
Undergarments	Undershirts, panties, bra liners, lining,
Accessories	Scarfs, socks, gloves, tote bag
Kitchen textiles	Towels, dish cloths, napkins, table cloths, rags, wash cloths
Home furnishings	Curtains, rug, decorative pillows, seat covers, upholstery, couch covers
Bedding	Blankets, sheets, pillow cases, shams,
Other	See through garments, beach cover-ups, fashion garments, medical gauze, baby apparel, children's apparel, neck tie

Consumer purchasing responses

In the third part of the physical hand evaluation evaluators were asked two questions on their purchasing decisions of sustainable tee shirts. The questions that were asked were;

Q1: Would you be more likely to purchase a tee shirt knowing it is sustainable?

Q2: Are you willing to pay more for a tee shirt knowing it is sustainable?

Evaluator's responses verified that when apparel is sustainable it does have a higher value to the consumer, and is more likely to be purchased. This response rate further validates that although the bast fiber fabrics didn't rank as high in comfort as the Fabric D and E, Fabrics B and C have an advantage over Fabric D because they are more sustainable. Figure 23 shows the breakdown of responses for question one.

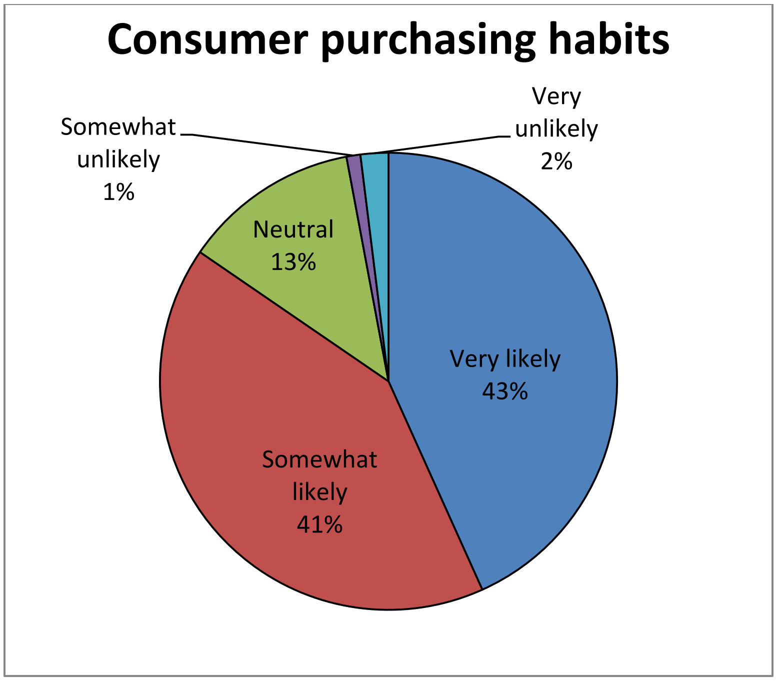

Figure 23: Consumer purchasing habits
Note: Question- Would you be more likely to purchase a tee shirt knowing it is sustainable?

Evaluator's responses showed that they were very likely to purchase a tee shirt knowing it was sustainable but that they were only somewhat likely to pay more for that tee shirt. Figure 24 shows the breakdown of responses for question two: Are you more likely to pay more for a tee shirt knowing that it is sustainable?

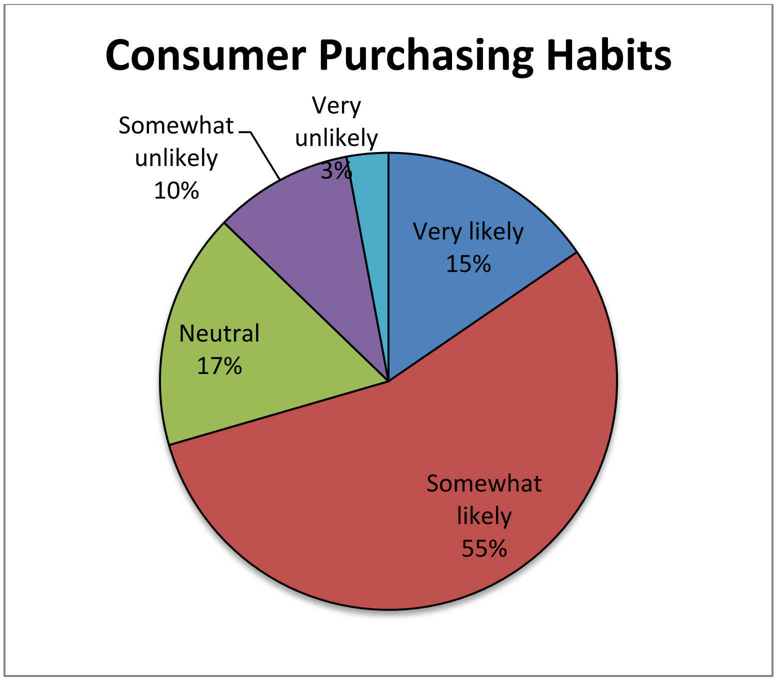

Figure 24: Consumer purchasing habits
Note: Question-Are you more willing to pay more for a tee shirt knowing it is sustainable?

Although the response rate falls from very likely to somewhat likely when addressing price, the majority of evaluators still are somewhat likely to purchase the tee shirt, even if it is more expensive. This information validates the move to a more sustainable industry would be relatively accepted by the consumer. Also, while analyzing this data, it showed that bast fibers may have more success in even more value added products such as blouses, dresses, and home textiles, which are products that consumers already expect to pay more for. A tee shirt is such a basic product, but if more thought was given towards design, the products with bast fibers may be even more readily accepted into the market.

CHAPTER 5: CONCLUSIONS

Technological advancements are continuously improving for bast fiber fabric production. These advancements will help improve the sustainable aspects of the fabrics, and to enhance the attribute of these fabrics. As developments improve, properties such as texture and blend-ability will also improve. Already these advancements have made it possible for bast fibers to work on cotton spinning equipment and to be made into knit fabrics. With these advancements come new product opportunities as well as an increase of sustainable products for the textile industry.

The data collected in this research demonstrates the potential bast fibers have for textile product lines. This research successfully met the objectives to contact companies, interview industry professionals about their opinions and knowledge on bast fibers, and to adapt and administer a survey instrument testing the physical attributes of fabric hand, specifically how bast fiber fabrics compared to each other and to other types of fabrics. The major findings of this research included;

- Assessing the extent to which bast fibers are currently being used by companies interviewed in this research.
- Assessing the viability of bast fibers as sustainable textiles.
- Evaluating how bast fiber knit fabrics rate in comparison to one another and to other fiber content knit fabrics for comfort and fabric attributes (cool/warm, dry/wet, smooth/rough, bald/hairy, thin/thick, flexible/stiff, stretchy/ non-stretchy).

- Evaluating how bast fiber knit fabrics rank in comparison to one another and to other fiber content knit fabrics in tee shirt applications.

This research provided a foundation for bast fibers to be utilized as high value products in the apparel industry. A review of literature was conducted to collect data on the properties of bast fibers, and their past use in the industry and potential for future implementation. The literature review demonstrated the properties that bast fibers obtain, as well as the complications and disadvantages that are associated with bast fiber production. Although the sustainability of some bast fibers (primarily hemp and flax) has begun to be researched, the literature provided limited information demonstrating the entire life cycle assessment (LCA) of these fibers from farm to fashion. The literature demonstrated that hemp and flax have the highest potential to grow and be accepted into the apparel and interiors market, while other bast fibers seem to have high potential to be used in the industrial textiles market and composites market. The literature also allowed that further developments in processing would likely improve the LCA of any bast fiber production.

The objective of this research is to demonstrate the potential for bast fibers to be accepted into the textile industry as a sustainable material. The research determined potential uses of bast fibers as well as their acceptance by the consumer through judgment of their sensory perception. This research also aimed to determine general opinions and attitudes towards these fibers in the development of end products such as apparel. These objectives were accomplished by two phases. Phase One, gave insight into the industry, and whether companies were interested in using, or already using bast fibers in their products.

Phase One was conducted through a series of three interviews with companies in the industry. Through these interviews, a qualitative research method was used to analyze the data and to respond to research questions one through four.

Phase Two, determined consumer acceptance of bast fiber textiles through a physical fabric hand evaluation method. With no one subjective fabric hand evaluation method being considered the standard, key publications were observed in order to develop a subjective hand evaluation method that was appropriate for this study. This research looked at several publications which included AATCC Evaluation Procedure 5: guidelines for the subjective Evaluation of Hand (2006), Civille and Dus (1990), and Harada, T., et. al. (1971), among others mentioned throughout this research.

Prior to beginning the physical hand evaluation, the procedure was validated by TPACC specialists, as well as industry members who participated in the interviews. These industry professionals helped validated what fabric type and weight to use in the evaluation procedure as well. Five fabrics were chosen for the evaluation. One 100% cotton knit fabric was chosen because of its wide spread use in apparel products (specifically tee shirts). One blend of recycled polyester/organic cotton was chosen as a comparative sustainable knit fabric. One organic cotton/hemp knit blend, one 100% hemp knit fabric, and one 100% linen knit. Once the fabrics were decided upon, and received, they were prepared in accordance to the AATCC Evaluation Procedure 5. All five fabric samples were washed, cut into 8x8 inch (20.3cm x 20.3 cm) squares, enough for each evaluator to use a fresh sample, and then marked with a permanent marker before subject evaluation.

The experiment was comprised of three parts, a rating section, a raking section and demographics and consumer purchasing questions. The rating section asked evaluators to rate each of the five fabrics for comfort and seven attributes- cool/warm, smooth/rough, wet/dry, bald/hairy, thin/thick, flexible/stiff, stretchy/non-stretchy. The samples were presented to the evaluators, one at a time in random order, and kept from their view.

In part two of the survey evaluators were asked to conduct a simple ranking procedure. Evaluators were shown a picture of a tee shirt, and were then blindfolded so that the fabrics would be kept from their view. The fabrics were then placed in front of them in random order, on a non-textured, non-metal table. The evaluators were then asked to rank the fabrics in order from most desirable for the product to least desirable for the product. Through the statistical program SAS, summary statistics and t-tests were conducted to analyze the data as well as some qualitative data was analyzed by the principal investigator to respond to research questions five and six.

Summary of Results

Through the data collected in this research it is clear that bast fibers have the potential to be used as apparel and interior products and to be accepted into the market. Although these fabrics were not rated among the top fabrics for hand, they were not totally unacceptable and evaluators expressed a high rate of responses for possible product categories for these fabrics. Evaluators also expressed a high value in sustainable products when answering the consumer purchasing behavior questions in the survey, which validates that these materials will add value to the products they are used in.

There were six research questions that were answered through this research;

RQ1: Are companies currently using bast fibers in their products, why or why not?

According to companies A, B, and C, bast fibers are on the forefront of development in all of the interviewed companies. Companies A and C are both experimenting with bast fibers as blends in their research and development departments and with product development teams. Both companies see a potential for bast fibers in the market, and believe that they add a substantial amount of value to a product because of their sustainable aspects. Company A's products are all 100% hemp or blended hemp with organic cotton. Company A's mission is to spread the word about hemp and its beneficial properties in textiles as well as in toiletry products and food. Some disadvantages were mentioned when experimenting with bast fibers by Company A and C. Company A mentioned there were some complications with the drape of the bast fibers. The drape disadvantage wasn't that it didn't have good drape but that the drape was more body conscious. This means that the fabric draped in a way that it would show off the curves of the natural body. This aspect could be thought of as an advantage in certain products, but Company A was specifically working with sports apparel and casual wear that this was not an aspect that lent itself well to the end product. This aspect is also visible in the results from the hand evaluation. Some comments from the evaluators mentioned that the Fabric B and C seemed to have a drape that would be applicable to a more formal garment, rather than a tee shirt. Company C mentioned that they used the bast fibers for their unevenness to achieve a more rustic, homespun look. This aspect of the fibers could be considered both an advantage on some applications and a disadvantage in other applications. The aspect of texture was found to be true in the results of the hand evaluation as well, and comments from evaluators expressed that there was texture present in the bast fiber fabrics, but that it didn't necessarily result in discomfort.

RQ2: Are bast fibers a viable option for the sustainable apparel industry according to industry members?

All companies involved in the interviews think that bast fibers could work in the industry. Company B is biased as they sell only bast fiber products, but Company A and Company C do not sell products that include bast fibers. Company A is very interested in incorporating bast fibers into their product lines. Company B considers bast fibers, specifically hemp a more viable option for the interior market because of certain qualities such as strength and low elongation and its ability to recover, and not loose shape. These properties will lend themselves well to upholstery and products that have the fabric pulled tight and receive high wear and tear. According to the hand evaluation, the bast fibers rated high among product categories that were higher end, such as tops and dresses. Fabrics B, and C also rated high for accessories such as scarfs as well as bedding and Fabric A rated highest among kitchen and home textiles.

RQ3: Is the survey instrument (for Phase Two) thorough and comprehensive for evaluating bast fiber fabrics compared to other fabrics in the industry?

Company A looked extensively at the survey instrument and aided in some of the question validation as well as put input into the question clarification and important questions to include. All three companies were interested in the results and allowing their fabrics to be involved in the testing. Although companies A and C do informal hand tests within their companies, they do not do extensive hand testing equivalent to this procedure. All companies validated the survey and put their input on what questions are important to find out from their consumers.

RQ4: What types (content, structure, weight) of fabrics would be beneficial to use in the survey instrument (used in Phase Two).

This question was validated through nominations from companies. Company A which makes knit tee shirts thought that hand was an important aspect of close to skin garments such as the tee shirt. The company was interested in including one of their more popular fabrics in the testing procedure. Knit fabrics and a basic tee shirt as the end product was decided on from the input of both Company A and B because these would be the fabrics that could not otherwise be tested for fabric hand on the Kawabata instrument and were the most important based on their end product as typically being used in apparel. Woven fabrics and interior products were considered but rejected because they are less often made into products where hand is the most important aspect. The tee shirt is also a commodity product and therefore would be of interest for all evaluators (non-dependent on gender, race, or nationality).

Phase Two research questions:

RQ5: How do bast fiber knit fabrics rate in comparison to one another and to other fibers for comfort and fabric attributes (cool/warm, dry/wet, smooth/rough, bald/hairy, thin/thick, flexible/stiff, stretch/ non-stretchy, comfortable/uncomfortable)?

This question was answered in the rating section of the survey instrument. Quantitative and qualitative data was analyzed to verify the results. Figure 25 shows an overview of the attribute ratings and how they correlate with the comfort rating. The word in the parentheses shows the rating that has a positive correlation with the next attribute in the hierarchy. Moisture was not included in the table because the results did not significantly relate to any of the other attributes.

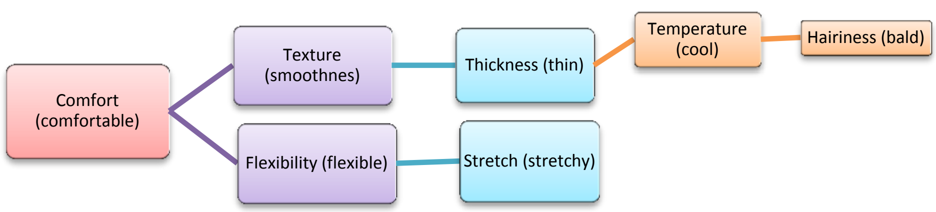

Figure 25: Attribute Ratings Relationship to Comfort

Table 18 shows each attribute ratings and how the fabrics rated in each (their mean values). Highlighted is the fabric that rated the highest (most closely related to comfort). See table 10 for the rating scale.

Table 18: Fabric attribute mean ratings

Attribute		Fabric &	Mean		
	Fabric A	Fabric B	Fabric C	Fabric D	Fabric E
Comfort	2.87	3.58	3.63	4.15	4.50
Temperature	2.98	2.09	2.13	2.91	2.76
Moisture	1.96	2.57	2.46	2.34	2.43
Texture	2.25	3.12	2.75	4.11	4.13
Hairy	3.03	2.49	2.86	2.74	2.84
Thickness	3.12	2.16	1.53	2.74	2.40
Flexibility	3.63	4.13	4.43	4.03	4.43
Stretch	3.24	3.26	3.89	3.57	4.42

As shown in Table 18, Fabric E was rated the most comfortable, but all fabrics except Fabric A rated above neutral, meaning that they were all considered to be comfortable. The qualitative data summary describes that evaluators chose Fabric B and C as somewhat comfortable only because of the presence of texture, and not because if discomfort. Evaluators also mentioned that Fabric B and C had nice drape ability, but could be used for apparel products not used directly against the skin because of this texture. Table A also shows that Fabric C (bast fiber) and E (sustainable) rated highest for flexibility which has a direct correlation to comfort.

The majority of the evaluators also placed a higher premium on sustainable products stating that they would be more likely to purchase a product if it was sustainable, and that they are somewhat likely to purchase the product if it is sustainable and more expensive. Fabric B was rated the coolest among the fabrics which does not have a direct relationship with comfort. Fabric C was rated very similarly in temperature. These two fabrics were also rated the thinnest of the fabrics.

After evaluating all of the data (quantitative and qualitative), it has been proven that the bast fiber fabrics would be accepted into the market as a sustainable material. However tee shirts may not be the best product line for bast fibers to enter into the market in. It appears by analyzing the data, that the bast fibers would be better suited for higher value added products which would benefit more from the properties that these fibers demonstrate.

RQ6: How do bast fiber fabrics rank in comparison to one another and to other fibers in the use of a t-shirt?

Overall Fabric A, organic cotton/hemp blend was the fabric that was most often placed in the least desirable location, while Fabric E, organic cotton/recycled polyester was most often placed in the most desirable position. The Figures 11-15 on page 113 - 114 show the percentages that each fabric was ranked from most desirable (one) to least desirable (five). This part of the evaluation was coupled with qualitative results as well, that determined that Fabric C and B were rated lower because of its feeling of lightness (although not technically lighter) the fabrics had a lighter feel and therefore were not suitable, according to the evaluators, for the use in a tee shirt. They did however rate high in other categories of products, see Table 16.

According to the results from the interviews, as well as investigated in the literature review, hemp and flax seem to be the most likely bast fibers to succeed as high value added products such as apparel and home textiles. Advancements are still needed for full market acceptance but if put into the right applications, the results of this study show that they are likely to succeed.

5.2 Limitations

Due to time restraints and the scope of this study, only North Carolina residents were used to evaluate this study, and primarily students and individuals with textile backgrounds. The availability of hemp fabrics in the United States is limited because of legal issues for processing within the United States. Processing of bast fibers is slowly becoming further developed as the interest and demand from consumers begins to rise. Because the demand is not high, the lack of bast fiber knits remains a limitation for obtaining uniform weight, finish and structured fabrics for samples used in this research. Limited research has been conducted which would provide concrete information on the level of sustainability of the overall process of the fibers from seed to product although bast fibers are known to use fewer fertilizers and pest control, as well as significantly less water than conventional and organic cotton. Lack of clear concise definitions of terms such as; green, environmentally friendly, sustainable, and eco-friendly must be taken into account until pure transparency is gained. There is a degree of green washing within the textiles industry. A relatively limited number of evaluators, range of male and female respondents, as well as a small range in age and ethnicity make it difficult to generalize results across different demographic groups. While the results of this study cannot be generalized to all consumers because of the use of a convenient sample, the increasing population of people interested in making ethical and environmentally sustainable product choices makes this topic worth elaboration and continued investigation. The evaluators chosen for this study were limited to students, primarily within the textile and fashion design and management degrees who would be able to make an evaluation on the materials, and who were available during the time period of the study. Although the use of a convenient sample can cause a biased result, the benefits of using a convenient sample in this circumstance resulted in more educated responses in fabric hand and application. The convenient sample is not an accurate representation of a larger group or population of people. The convenient sample used in this research is not equally dispersed in male female ratio, nor is there a large range of ages represented in this study. Equalizing this in the sample could result in significantly different data.

Fabric types, weight of fabrics, finishes on fabrics, and construction of fabrics were based on achievable fabrics and donated fabrics from companies and may not reflect the most uniformity across samples. Two Fabrics (D and E) were finished with a softening agent, while the other three fabrics were not, this could cause some variation in true hand of fabric.

The term *somewhat*, was misleading for the principal investigator when analyzing the data. Using *comfortable* instead of *somewhat comfortable* (for example) could have been more straightforward for the evaluator's choices, or extending the Likert scale to a 7 point scale and including both ratings.

Using the tee shirt as the only product may have limited the results because of the differences in fabric types. Many evaluators may have ranked the fabric in the way that they did because of what they are more accustomed to feeling as a tee shirt. Since Fabric D and Fabric E are already used in tee shirt production, evaluators could have been more likely to rank them first. Possibly including several other products would have yielded different results.

5.3 Future research

Future research should be conducted to obtain further information on the acceptance of bast fibers as a suitable, sustainable material for textile product development. This research has led to the following recommendations for future research opportunities;

1. Expand the geographical region, sample size, gender, age range and background of participants
    a. Expand the sample population region to outside of the southeast.
    b. Expand the sample population to outside of the U.S.
    c. Have equal male and female respondents
    d. Expand age range.
2. Obtain all fabric samples of the exact same weight, finish, structure.
    a. Explore applications of softeners

    b. Explore variation of fabric weights for varied end uses

3. Reword some of the survey for clearer responses
    a. Smooth/rough attribute could be altered to textured/non-textured for clarity
    b. Taking out the word somewhat may be more clear to evaluator and principal investigator
4. Expand focus to wider apparel market, not specifically tee shirts.
    a. Fashion apparel
    b. Outerwear
    c. Sports or performance wear
5. Expand focus to interior textiles
    a. Bed linens
    b. Table linens
    c. Curtains draperies
    d. Kitchen textiles
    e. Upholstery
    f. Decorative accessories
6. Expand focus to consumer needs/wants for fabrics
    a. Explore appropriate end uses (i.e. accessories)
    b. Explore gender bias with regard to end use
    c. Explore what's appropriate for the unique properties that bast fibers possess

7. Expand evaluation to include sight
    a. Explore how sight could change consumer response to fabrics
    b. Explore how the sight of the fabric may change the ideal end use
8. Expand study to include wear trials
    a. Educate the participants on new fabrics
    b. Explore if texture irritates the skin of the participants
    c. Overcome traditional knit tee shirt textures
9. Examine comparable weight for apparel fabric purchases
    a. Consumers consider fabric weight when purchasing
    b. Bast fibers feel considerably lighter than cotton fabric of similar weight
10. Expand research to include price
    a. Explore how price would affect buying behaviors
11. Expand research to include dyeability and printability
    a. Explore the ability to dye, print or decorate the textiles for added benefits and interest from consumers
12. Research Life Cycle Analysis of bast fiber fabrics as compared to other natural fibers
    a. Create a comparison matrix
    b. Educate consumers on benefits of purchasing sustainable products
13. Expand hand test to incorporate other senses
    a. Have evaluators include sight into their evaluations
    b. Conduct a wear test with garments made form bast fibers

In summation, this investigation will add to the knowledge base for the research and development of bast fiber textiles in the use of high value added products such as apparel and accessories. This research is also beneficial to the growing sustainable textiles market. This research had several key findings which will be useful in industry and academia as they continue to develop bast fiber fabrics. Evaluators in this study found the bast fiber fabrics appropriate for dresses, fashion tops, skirts, home furnishings, accessories and undergarments which suggest there may be many product categories that are potential markets for these materials. Further research could focus on specific product markets to determine the acceptable market for bast fibers. Texture, or the sensation of smoothness and roughness, appeared to have a significant influence on the perception of comfort. Blending these fibers with fibers that will counteract the feeling of roughness, or looking into softeners or fiber uniformity may be useful to the success of these fibers in certain markets. Determining acceptable textures will be critical in the success of bast fibers in the apparel industry. Like many new materials, consumers may need to be educated to understand the opportunities and benefits of buying and supporting sustainable products. Although the bast fiber fabrics were not concluded to be the most comfortable when compared to other fabrics, they did rate relatively high in most categories, and it appears that with some further research, there is a niche in the market for these materials.

REFERENCES

Akin, D., Dodd, R., Perkins, W., Henriksson, G., Eriksson, K., (200).

Spray Enzymatic Retting: A method for Processing Flax Fibers. Textiles Research Journal 70(6), p.486-494

Alden, M. D., Proops, J., Gay, W.P. (1998)

Industrial Hemp's Double Dividend: A Study for the USA. *Ecological Economics* 25. P. 291-301.

Alex, R., Kessler, R., Kholer, R., Mayer, G., Tubach, M. (2004).

Sustainability and profitability through value chain management in bast fiber processing. Journal of Natural fibers 1(3), p.67-75.

American Association of Textile Chemists and Colorists (AATCC). (2001).

Evaluation Procedure 5: Guidelines for the subjective evaluation of fabric hand. In *AATCC Technical Manual* (pp. 684-685). New York: Howes.

Baugh, G. (2008).

Fibers: Clean and green fiber optics. In J. Hethorn, & C. Ulasewicz (Eds.), Sustainable fashion, why now? A Conversation about Issues, Practices, and Possibilities (pp. 326-357). New York: Fairchild books, Inc.

Beard, N. D. (2008).

The Branding of Ethical Fashion and the Consumer: A Luxury Niche or Mass-market Reality? *Fashion Theory,* 12(4), 447-468. Retrieved December, 03, 2010, from Textile Technology Index.

Bel-Berger, P, Von Hoven, T, Ramaswamy, G.N., Kimmel, L, & Boylston, E. (2009) Cotton/Kenaf Fabrics; a Viable Natural Fabric. Journal of cotton sciences. 3(2) 60-70.

Bengtsson, E. (2009) Obtaining High Quality Textile Fiber From Industrial Hemp Through Organic Cultivation. *The Horticulture Programme 3.*

Bernard, J. C.. (2008) Consumer Willingness to Pay for Sustainable Apparel: The Influence of Labeling for fibre Origin and Production Methods. *International Journal of Consumer Studies.* 32. 491-498.

Borio, G., (2000) Tobacco Timeline: The Twenty-First Century-The New Millennium. Tobacco.org Web. http://www.tobacco.org/resources/history/Tobacco_History21.html

Bruntland Commission (1987). Our Common Future. *United Nations World Commission On Environment and development.* Oxford University Press.

Cheek, L. (1990). Dyeing and Colorfastness of Direct-Dyed Ramie in Comparison to Flax and Cotton. *Clothing and Textiles Research Journal,* 8 (38).p. 38-42.

Civille, G. V. and Dus, C. A. (1990).

Development of terminology to describe the hand feel properties of paper and fabrics. *Journal of Sensory Studies*, 5, 19-32.

Clark, H. (2008).

Slow + Fashion- an Oxymoron, or a Promise for the Future? *Fashion Theory,* 12(4), 427-446. Retrieved December, 06, 2010, from Textile Technology Index.

Clarke, R. C. (2010)

Traditional Fiber Hemp (cannabis) Production, Processing, Yarn Making, and Weaving Strategies- Functional Constraints and Regional Responses. Part 2, *Journal of Natural Fibers,* 7 (3) p. 229-250.

Clemons, C. M., Caulfield, D. F. (2005).

Natural Fibers. *Functional fillers for plastics.* Newark, NJ: Wiley-VCH

Cockcroft, C., (2001).

Science: Hemp hits its stride: The cousin of cannabis is perfect for an industry looking for greener resources. *The Guardian (London)* (0261-3077), p. 2.

Denton, MJ., Daniels, PN. (2002)

Textiles Terms and Definitions. 11th Edition. *The Textile Institute:* Manchester.

Franck, R. (2005)

Bast and Other Plant Fibers. Cambridge England: Woodhead publishing In Textiles,2005. Print.

Harada, T., Saito, M., Matsuo, T. (1971)

Study on the Hand. *Based on the Journal of the Textiles Society of Japan*. 24 (7/8) P. 126-138.

Hearle, J.W.S. (1993)

Can Fabric Hand Enter the Dataspace? Measuring the Unmeasurable? *Textile Horizons International.* 13 (3). P.16-20

Hudson, P. B., Clapp, A. C., & Kness, D. (1993).

Joseph's Introductory Textile Science. Orlando, FL: Harcourt Brace Jovanovich.

Hussey, Clare. (2011).

Waste Textiles, Recycling. Textiles, the Quarterly Magazine of the Textiles Institute 38.3/4 (2011): 36-37. Print.

Kadolph, S. J., & Langford, A. L. (1998).

Textiles eighth edition. Upper Saddle River, New Jersey: Merrill.

Kessler, R.W., Kohler, R., Mayer, G., Tubach, M. (2000)

New Economical Chances for Flax and Hemp Fiber Upgrading. *Bio-resource hemp,* 2000, 1-11.

Koch,W (2010).

Hemp Homes Are Cutting Edge of Green Building. *USA Today.* Web. http://content.usatoday.com/communities/greenhouse/post/2010/09/hemp-houses-built-asheville/1

Laun,A. (2011)

Developing Strategies for Beginning T-shirt Companies. *Graphic communication Department.* California Polytechnic State University. 2011.

Lin, T. (2005).

Sustainable Development: Building a case for Hemp. *Journal of Textile and Apparel, Technology and Management,* 4(3), 1-16. Retrieved December, 06, 2010, from Textile Technology Index.

Munder, F., Hempel, H. (2006)

Mechanical and Thermal Properties of Bast Fibers Compared to Tropical Fibers. *Institute of Agricultural Engineering,* 448. P. 197-209.

Ning Pan, S., Zeronian, Haig, and Ryu, Hyo-Seon. (1993)

An Alternative Approach to the Objective measurement of Fabrics. *Textile Research Journal* 63 (33). P.33-43.

Papanek, V. (1971).

Design for the real world: Human ecology and social change (1st American ed.). New York: Pantheon Books.

Peirce, F.T

The “Handle” of Cloth as a Measureable Quantity. *The Journal Of The Textile Institute.* 21 (1). P. 377-402.

Porter, S.,Umbach, P. (2006).

Student Survey Response Rate Across Institutions: Why Do They Vary? *Reasearch in Higher Education.* 47(2). P. 229-247

Ramaswamy, G., Craft, S., Wartelle, L. (1995).

Uniformity and Softness of Kenaf Fibers for Textile Products. *Textile research journal.* 65(12). P. 765-770.

Rothenburg, E (2001)

A Renewal of Common Sense: The Case for Hemp in 21st Century America. Votehemp.inc

Rymsza, T. (1998)

Creating High Value markets For Kenaf Paper, A commercial Experiment. Presented at the First Annual Conference of the American Kenaf Association. San Antonio, Texas.

Singh, B. (2003)

"Working for the Sustainable Environment." International Jute Study Group. N.p.,. Web. 17 Jan. 2012. <http://www.jute.org/sustainable_env.htm>.

Svennerstedt, B. (2009)

Hemp Fiber Strength an Thickness: A study of Plant Development of Sweedish Grown Industrial Hemp. *Journal of Natural Fibers*, 6(4), p. 295-302.

Thomas, A. (2009)

Design and Sustainable Development: What is the contribution that design can make? A Case Study of the Welsh Wollen Industry. *Design Research Society Conference 2008*, Sheffield Hallem University, Sheffield, UK, 16019 July 2008.

Turunen, L., Van der Werf, H. (2006)

Life Cycle Analysis of Hemp Textile Yarn. Comparison of Three Fiber Processing Scenarios and a Flax Scenario. French National Institute for Agronomy Research.

Van der Werf, H. M. G., Mathijssen, E. W. J. M., Haverkort, A. J. (1996).

The Potential of Hemp (cannabis sativa L.) for Sustainable Fiber Production: a Crop Physiological appraisal.

Van der Werf, H. M.G., Turunen, L. (2007)

The Environment impacts of the production of Hemp and Flax textile Yarn. *Industrial Crops and Products* 27(1). P.1-10.

Wang, W., Cai, Z., Yu, J. (2008)

Study on the Chemical Modification of Jute Fiber. *Journal of Engineered Fibers and Fabrics. 3 (2). P. 1-8.*

Webber, C.L., III, V.K. Bledsoe, and R.E. Bledsoe. (2002)

Kenaf Harvesting and Processing. 9. 340–347. In: J. Janick and A. Whipkey (eds.), Trends in new crops and new uses. ASHS Press, Alexandria, VA.

Young, C., Jirousek, C., Ashdown, S. (2004)

Undesigned: A Study in the Sustainable Design of Apparel Using Post Consumer Recycled Clothing.*Clothing and Textile Research Journal,* 22 (1/2), 61-68.

Zahran, M.K., Ahmed, H.B. (2009)

A Greener Approach for Full Flax Bleaching. Journal of the Textile Institue, 101 (7). P 674-678.

APPENDIX

APPENDIX A:

Informed Consent Form for Industry Participation
Study: Bast Fiber Research

Principal Investigators: Claire Stanhope Faculty Sponsor: Dr. Lisa Parrillo-Chapman

Hello,

My Name is Claire Stanhope and I am a graduate student conducting my thesis research. I would like to invite you to participate in a research study about sustainability in the textiles industry. My research specifically investigates bast fibers as a potential mainstream material for the apparel industry. This research project is being conducted by myself, Claire Stanhope, Dr. Lisa Parrillo-Chapman , Dr. Trevor Little, and Dr. Katherine Carroll. The purpose of this research is to investigate bast fibers and their potential for high value added products in the sustainable textiles industry. This study also aims to evaluate consumer's response to this type of textile product through a subjective fabric hand evaluation method. Specifically this research will evaluate response to exposure of these types of materials and their potential to become a more mainstream textile in the apparel and interior markets. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty.

There is no danger or risk in participating in this study. The information gained in this research will be completely anonymous and will not be linked directly to you or your company. There are no costs involved in participating in this study. The information collected from this study will not benefit you directly, but will provide benefits to my study and other researchers.

The results of this study will be reported with no reference to your identity or the identity of your company. The questions asked in this study will be about the use of bast fiber materials and your opinions, knowledge and awareness of these materials. If you choose to participate, please do not mention any proprietary company info. No reference will be made in oral or written reports which could link you to the study. This information obtained will not be used to reference your identity in published data.

If you agree to participate in this study, you will be asked to give your input on the use of bast fibers in the textile industry. I will also be asking you to discuss common fabric evaluation processes relating to the hand of fabrics that are practiced in the industry. This will be conducted through an informal conversational interview method over the phone or through email.

Once interviews have been completed, I will type you responses and send them to you to verify. You may at this time choose to omit, change, or rephrase any or all of the information.

If you have questions at any time about the study or the procedures, you may contact the principal investigator, Claire Stanhope, at cmstanho@ncsu.edu, or by phone at 8287134517.

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent to Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature_________________________________ Date _______________

Investigator's signature_____________________________ Date _______________

APPENDIX B:

PHYSICAL HAND EVALUATION SURVEY:

Claire- Subjective Fabric Hand Test (fabric rating)

1. The purpose of this study is to gain better understanding of the response and personal preference that people have to certain types of fabric hand.

Your participation in this study is voluntary and you may chooses to stop participating at any time.

If you have any questions during or after taking this survey, please contact the researcher (Claire Stanhope or Lisa Parillo Chapman)

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919-515-4514).

By checking the "I accept" box I acknowledge I have read and understand the above information and am over the age of 18. I may print a copy of this agreement for my records. I agree to participate in this study with the understanding that I may withdraw at any time.

☐ I accept ☐ I do not accept

Claire- Subjective Fabric Hand Test (fabric rating)

Demographics

Please provide the following demographic information about yourself.

2. Are you Male or Female?

- [ ] Male
- [ ] Female

3. How old are you?

4. What is your Major?

- [ ] Fashion and Textile Management
- [ ] Fashion and Textile Design
- [ ] Polymer and Color Chemistry
- [ ] Textile Engineering
- [ ] Textile Technology
- [ ] MS
- [ ] MT
- [ ] Other
- [ ] Professional (non-student)

5. What is your ethnicity?

- [ ] White/ caucasion
- [ ] Asian
- [ ] African American
- [ ] Pacific Islander
- [ ] Hispanic
- [ ] Other (please specify)

Claire- Subjective Fabric Hand Test (fabric rating)

Part 1- Fabric Rating

Each question in this section addresses a fabric attribute.Evaluate the attribute to the best of your abilities by feeling the fabric.

Use your non-dominant hand to evaluate the fabrics as desired. You may use your dominant hand to hold the fabric in place while evaluating with your non-dominant hand.

Please rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated. Once you have answered the question, please move on to the next.

6. Ask the proctor for the applicant ID and fabric ID, Please do not continue before this is filled out.

Applicant ID

Fabric ID

Claire- Subjective Fabric Hand Test (fabric rating)

7. Please rate the fabric warmth/coolness to the attribute that most closely relates to what you feel.

	Very cool	Cool	Neither cool nor warm	Warm	Very Warm
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

8. Please rate the fabric dryness/wetness to the attribute that most closely relates to what you feel.

	Very dry	Dry	Neither dry nor wet	Wet	Very wet
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

9. Please rate the fabric smoothness/roughness to the attribute that most closely relates to what you feel.

	Very smooth	Smooth	Neither smooth nor rough	Rough	Very rough
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

10. Please rate the fabric baldness/fuzziness to the attribute that most closely relates to what you feel.

	Very bald	Bald	Neither bald nor fuzzy	Fuzzy	Very Fuzzy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

11. Please rate the fabric thinness/ thickness to the attribute that most closely relates to what you feel.

	Very thin	Thin	Neither thin nor thick	Thick	Very thick
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

12. Please rate the fabric flexibility/stiffness to the attribute that most closely relates to what you feel.

	Very flexible	Flexible	Neither flexible nor stiff	Stiff	Very stiff
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

13. Please rate the fabric on non-stretchy/stretchiness to the attribute that most closely relates to what you feel.

	Very non-stretchy	Non-stretchy	Neither non-stretchy nor stretchy	Stretchy	Very Stretchy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

14. Please rate the fabric on the level of comfortable/uncomfortable (for a t-shirt) that most closely relates to what you feel.

	Very Comfortable	Comfortable	Neither comfortable nor uncomfortable	uncomfortable	Very uncomfortable
checking the circle that you feel best reflects the intensitylevel of the attribute being evaluated	○	○	○	○	○

Claire- Subjective Fabric Hand Test (fabric rating)

15. Please write down any additional feelings you may have had, or any additional thoughs you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

16. Now that you have evaluated this fabric, in what type of product would you expect to find this fabric? Please be as specific as possible:

Claire- Subjective Fabric Hand Test (fabric rating)

Next Fabric Sample

Please notify the proctor that you are ready for the next fabric sample.

Claire- Subjective Fabric Hand Test (fabric rating)

17. The proctor will give you the next fabric ID, Please do not begin before this information is filled out.

Fabric ID:

Claire- Subjective Fabric Hand Test (fabric rating)

18. Please rate the fabric warmth/coolness to the attribute that most closely relates to what you feel.

	Very cool	Cool	Neither cool nor warm	Warm	Very Warm
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

19. Please rate the fabric dryness/wetness to the attribute that most closely relates to what you feel.

	Very dry	Dry	Neither dry nor wet	Wet	Very wet
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

20. Please rate the fabric smoothness/roughness to the attribute that most closely relates to what you feel.

	Very smooth	Smooth	Neither smooth nor rough	Rough	Very rough
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

21. Please rate the fabric baldness/fuzziness to the attribute that most closely relates to what you feel.

	Very bald	Bald	Neither bald nor fuzzy	Fuzzy	Very Fuzzy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

22. Please rate the fabric thinness/ thickness to the attribute that most closely relates to what you feel.

	Very thin	Thin	Neither thin nor thick	Thick	Very thick
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.					

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

23. Please rate the fabric flexibility/stiffness to the attribute that most closely relates to what you feel.

	Very flexible	Flexible	Neither flexible nor stiff	Stiff	Very stiff
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

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Claire- Subjective Fabric Hand Test (fabric rating)

24. Please rate the faric on the level of non-stretchy/stretchiness that most closely relates to what you feel.

	Very non-stretchy	non-stretchy	Neither non-stretchy nor stretchy	Stretchy	Very Stretchy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

25. Please rate the fabric on the level of comfortable/uncomfortable (for a t-shirt) that most closely relates to what you feel.

	Very Comfortable	Comfortable	Neither comfortable nor uncomfortable	uncomfortable	Very uncomfortable
checking the circle that you feel best reflects the intensitylevel of the attribute being evaluated	○	○	○	○	○

Claire- Subjective Fabric Hand Test (fabric rating)

26. Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

27. Now that you have evaluated this fabric, in what type of product would you expect to find this fabric? Please be as specific as possible:

Claire- Subjective Fabric Hand Test (fabric rating)

Next Fabric Sample

Please notify the proctor that you are ready for the next fabric sample.

Claire- Subjective Fabric Hand Test (fabric rating)

28. The proctor will give you the fabric ID, Please do not start before this information is filled out.

Fabric ID:

Claire- Subjective Fabric Hand Test (fabric rating)

29. Please rate the fabric warmth/coolness to the attribute that most closely relates to what you feel.

	Very cool	Cool	Neither cool nor warm	Warm	Very Warm
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.					

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

30. Please rate the fabric dryness/wetness to the attribute that most closely relates to what you feel.

	Very dry	Dry	Neither dry nor wet	Wet	Very wet
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

31. Please rate the fabric smoothness/roughness to the attribute that most closely relates to what you feel.

	Very smooth	Smooth	Neither smooth nor rough	Rough	Very rough
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.					

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

32. Please rate the fabric baldness/fuzziness to the attribute that most closely relates to what you feel.

	Very bald	Bald	Neither bald nor fuzzy	Fuzzy	Very Fuzzy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.					

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

33. Please rate the fabric thinness/ thickness to the attribute that most closely relates to what you feel.

	Very thin	Thin	Neither thin nor thick	Thick	Very thick
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

34. Please rate the fabric flexibility/stiffness to the attribute that most closely relates to what you feel.

	Very flexible	Flexible	Neither flexible nor stiff	Stiff	Very stiff
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

35. Please rate the fabric non-stretchy/stretchiness to the attribute that most closely relates to what you feel.

	Very non-stretchy	Non-stretchy	Neither non-stretchy nor stretchy	Stretchy	Very Stretchy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

36. Please rate the fabric on the level of comfortable/non-comfortable (for a t-shirt) that most closely relates to how you feel.

	Very comfortable	Comfortable	Neither comfortable nor uncomfortable	Uncomfortable	Very Uncomfortable
Rate the fabric by checking the circle that you feel best relates the intensity levelof the attribute being evaluated.	○	○	○	○	○

Claire- Subjective Fabric Hand Test (fabric rating)

37. Please write down any additional comments that you may have had, or any thoughts that you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

38. Now that you have evaluated this fabric, in what type of product would you expect to find this fabric? Please be as specific as possible:

Claire- Subjective Fabric Hand Test (fabric rating)

Next Fabric Sample

Please notify the proctor that you are ready for the next fabric sample.

Claire- Subjective Fabric Hand Test (fabric rating)

39. The proctor will give you the fabric ID, Please do not start before this information is filled out.

Fabric ID:

Claire- Subjective Fabric Hand Test (fabric rating)

40. Please rate the fabric warmth/coolness to the attribute that most closely relates to what you feel.

	Very cool	Cool	Neither cool nor warm	Warm	Very Warm
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	◯	◯	◯	◯	◯

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

41. Please rate the fabric dryness/wetness to the attribute that most closely relates to what you feel.

	Very dry	Dry	Neither dry nor wet	Wet	Very wet
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

42. Please rate the fabric smoothness/roughness to the attribute that most closely relates to what you feel

	Very smooth	Smooth	Neither smooth nor rough	Rough	Very rough
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

43. Please rate the fabric baldness/fuzziness to the attribute that most closely relates to what you feel.

	Very bald	Bald	Neither bald nor fuzzy	Fuzzy	Very Fuzzy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

44. Please rate the fabric thinness/ thickness to the attribute that most closely relates to what you feel.

	Very thin	Thin	Neither thin nor thick	Thick	Very thick
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

45. Please rate the fabric flexibility/stiffness to the attribute that most closely relates to what you feel

	Very flexible	Flexible	Neither flexible nor stiff	Stiff	Very stiff
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

46. Please rate the fabric non-strechy/stretchiness to the attribute that most closely relates to what you feel.

	Very tight	Tight	Neither tight nor stretchy	Stretchy	Very Stretchy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

47. Please rate the fabric on the level of comfortable/non-comfortable (for a t-shirt) that most closely relates to how you feel.

	Very comfortable	Comfortable	Neither comfortable nor uncomfortable	Uncomfortable	Very Uncomfortable
Rate the fabric by checking the circle that you feel best relates the intensity levelof the attribute being evaluated.	○	○	○	○	○

Claire- Subjective Fabric Hand Test (fabric rating)

48. Please write down any additional comments that you may have had, or any thoughts that you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

49. Now that you have evaluated this fabric, in what type of product would you expect to find this fabric? Please be as specific as possible:

Claire- Subjective Fabric Hand Test (fabric rating)

50. The proctor will give you the fabric ID, Please do not start before this information is filled out.

Fabric ID: ____________________

Claire- Subjective Fabric Hand Test (fabric rating)

51. Please rate the fabric warmth/coolness to the attribute that most closely relates to what you feel.

	Very cool	Cool	Neither cool nor warm	Warm	Very Warm
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

52. Please rate the fabric dryness/wetness to the attribute that most closely relates to what you feel.

	Very dry	Dry	Neither dry nor wet	Wet	Very wet
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

53. Please rate the fabric smoothness/roughness to the attribute that most closely relates to what you feel.

	Very smooth	Smooth	Neither smooth nor rough	Rough	Very rough
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

54. Please rate the fabric baldness/fuzziness to the attribute that most closely relates to what you feel.

	Very bald	Bald	Neither bald nor fuzzy	Fuzzy	Very Fuzzy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

55. Please rate the fabric thinness/ thickness to the attribute that most closely relates to what you feel.

	Very thin	Thin	Neither thin nor thick	Thick	Very thick
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

56. Please rate the fabric flexibility/stiffness to the attribute that most closely relates to what you feel.

	Very flexible	Flexible	Neither flexible nor stiff	Stiff	Very stiff
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

57. Please rate the fabric non-stretchy/stretchiness to the attribute that most closely relates to what you feel.

	Very non-stretchy	Non-stretchy	Neither non-stretchy nor stretchy	Stretchy	Very Stretchy
Rate the fabric by checking the circle that you feel best reflects the intensity level of the attribute being evaluated.	○	○	○	○	○

Please write down any additional feelings you may have had, or any additional thoughts you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

58. Please rate the fabric on the level of comfortable/non-comfortable (for a t-shirt) that most closely relates to how you feel.

	Very comfortable	Comfortable	Neither comfortable nor uncomfortable	Uncomfortable	Very Uncomfortable
Rate the fabric by checking the circle that you feel best relates the intensity levelof the attribute being evaluated.	○	○	○	○	○

Claire- Subjective Fabric Hand Test (fabric rating)

59. Please write down any additional comments that you may have had, or any thoughts that you had while evaluating this fabric. Please note comments below:

Claire- Subjective Fabric Hand Test (fabric rating)

60. Now that you have evaluated this fabric, in what type of product would you expect to find this fabric? Please be as specific as possible:

Claire- Subjective Fabric Hand Test (fabric rating)

Part 2- Rating section

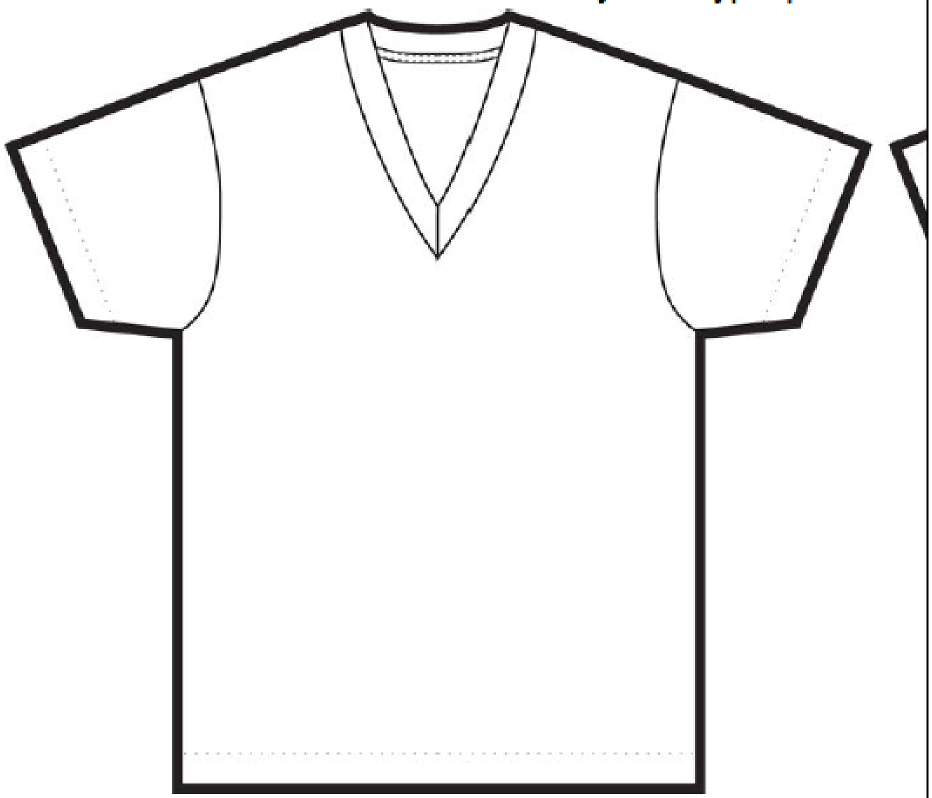
Please tell the proctor you have reached part two of the survey

you will be shown a picture and asked to rate the fabrics from most desirable fabric for this image to least desirable fabric for this image.

For this section, you will look at a product image and then will be blindfolded, you will then be given all of the fabrics to rank. If you are uncomfortable with this, you may choose to stop participating at any point.

Claire- Subjective Fabric Hand Test (fabric rating)

Look at this product and let the proctor you are ready for the blindfold. You will then rank the fabrics from most desirable to least desirable based on your sensory perseption



Claire- Subjective Fabric Hand Test (fabric rating)

61. Please give any feedback or comments that you have on the fabrics that you have just surveyed.

Claire- Subjective Fabric Hand Test (fabric rating)

Part 3: General Questions

This section will ask you a few general questions to gather information your opinions and buying habits towards sustainable apparel.

62. Would you be more likely to purchase a t-shirt knowing it is sustainable?

	Very likely	Somewhat likely	Neutral	Somewhat unlikely	Very Unlikely
Please check the circle that most closely describes your response to this question.	○	○	○	○	○

63. Are you willing to pay more for a t-shirt knowing it is sustainable?

	Very likely	Somewhat likely	Neutral	Somewhat unlikely	Very Unlikely
Please check the circle that most closely describes your response to this question.	○	○	○	○	○

APPENDIX C:

North Carolina State University

Institutional Review Board for the Use of Human Subjects in Research

REQUEST FOR EXEMPTION (Administrative Review)

GENERAL INFORMATION

1. **Date Submitted:** *Jan, 09, 2012*
2. **Title of Project:** *Acceptance of Bast Fiber Fabric Through Subjective Hand Evaluation*
3. **Principal Investigator:** *Claire Stanhope, Dr. Lisa Parrillo Chapman, Dr. Trevor Little, Dr. Katherine Carroll*
4. **Department:** *TATM* ______
5. **Campus Box Number:** ______
6. **Email:** Cmstanho@ncsu.edu______
7. **Phone Number:** *828-713-4517*
8. **Fax Number:** ______
9. **Faculty Sponsor Name and Email Address if Student Submission:** *Lisa Parrillo Chapman*
10. **Source of Funding? (required information):** ______
11. **Is this research receiving federal funding?** *No*
12. **If Externally funded, include sponsor name and university account number:** ______
13. **RANK:** Faculty: ☐ Student: ☐Undergraduate; ☐ **Masters;** or ☐ PhD Other (specify): ☐ _____

As the principal investigator, my signature testifies that I have read and understood the University Policy and Procedures for the Use of Human Subjects in Research. I assure the Committee that all procedures performed under this project will be conducted exactly as outlined in the Proposal Narrative and that any modification to this protocol will be submitted to the Committee in the form of an amendment for its approval prior to implementation.

Principal Investigator:

CLAIRE STANHOPE	Claire Stanhope*	Jan, 06, 2012
(typed/printed name)	(signature)	(date)

As the faculty sponsor, my signature testifies that I have reviewed this application thoroughly and will oversee the research in its entirety. I hereby acknowledge my role as the ***principal investigator of record****.*

Faculty Sponsor:

Dr. Lisa Parillo-Chapman	*	
(typed/printed name)	(signature)	(date)

***Electronic submissions to the IRB are considered signed via an electronic signature**

PLEASE COMPLETE AND DELIVER TO:

(carol_mickelson@ncsu.edu) or Institutional Review Board, Box 7514, NCSU Campus (Administrative Services III, Room 245)

****

For SPARCS office use only

Regulatory Compliance Office Disposition

☐ Exemption Granted ☐ Not Exempt, Submit a full protocol

Exempt Under: ☐ b.1 ☐ b.2 ☐ b.3 ☐ b.4 ☐ b.6

IRB Office Representative Date

Project Description: *Describe your project by providing a summary and answering the requests for information below.*

1. Project Summary. Please make sure to include the purpose and rationale for your study as well as a brief overview of your study.

This research will use a subjective hand evaluation to gather data regarding consumer's perceptions towards bast fiber fabrics. The data will be collected through performing a subjective hand test of several types of fabrics including the bast fiber fabrics for evaluation and comparison (See attachment A for procedure details).

2. Description of participant population, including age range, inclusion/exclusion criteria, and any vulnerable populations that will be targeted for enrollment.

The participants will be NC State Students, faculty and staff , 18 years and older, as well as other individuals who choose to participate. All testing will be done in a standardized testing facility within the College of textiles. Temperature and humidity will be recorded during each testing session. –not necessary in this section

3. Description of how potential participants will be approached about the research and how informed consent will be obtained. Alternatively, provide an explanation of why informed consent will not be obtained. Include a copy of recruitment materials, such as, scripts, letters of introduction, emails, etc. with your submission.

Students enrolled at NC State University over the age of 18 will be contacted during class time to participate in this voluntary test (see attachment A for procedure, and survey). The professors will be contacted to provide permission to enter the classrooms (see attachment B- email to professors). Once permission is granted, the researcher will explain the purpose and procedure before the survey is administered. Prior to completing the testing procedure a consent form will be provided for each student (see attachment C). The students will also be asked to participate out side of class, see attachment D for request letter).

4. Description of how identifying information will be recorded and associated with data (e.g. code numbers used that are linked via a master list to subjects' names). Alternatively, provide details on how study data will be collected and stored anonymously ("anonymously" means that there is no link whatsoever between participant identities and data). Describe management of data: security, storage, access, and final disposition.

The participants will be asked to complete the survey during class time or another designated period of time at a designated location. The testing procedure and survey will be voluntary and anonymous. Names will not be filled out on the questionnaire to ensure that anonymity is preserved. Researcher will not have access to individual's personal *information. Test results will be stored in faculty sponsor's office that only the faculty sponsor has access to.*

5. Provide a detailed (step-by-step) description of all study procedures, including descriptions of what the participants will experience. Include topics, materials, procedures, for use of assessments (interviews, surveys, questionnaires, testing methods, observations, etc.).

   1. *The professors of each classroom will be contacted via email in order to gain permission to use their class time for testing the students (see attachment B)*
   2. *The researcher will explain the purpose of the study (see attachment A).*
   3. *The researcher will briefly explain an overview of the evaluation procedure. (see attachment C).*
   4. *The testing procedure will be conducted with students and individuals 1-3 at a time by taking them into a separate, quiet room where the testing equipment will have been previously set up (see attachment A for testing procedure) Each individual that is being tested will then sign a consent form (Attachment C)*
   5. *Survey results will be stored in the faculty sponsors office at the College of Textiles and access will be granted to only the researcher and faculty sponsor, and statistical analyzer hired from SAS department at NC State.*
   6. *Review and statistical analysis of collected data will be conducted.*
   7. *Data results compiled and used as part of graduate student's thesis.*

6. Will minors (participants under the age of 18) be recruited for this study:

   No

7. Is this study funded? *No* If yes, please provide the grant proposal or any other supporting documents.

8. Is this study receiving federal funding? *No*

9. Do you have a significant financial interest or other conflict of interest in the sponsor of this project?
   No

10. Does your current conflicts of interest management plan include this relationship and is it being properly followed? *N/A*

11. **HUMAN SUBJECT ETHICS TRAINING**
    *****Please consider taking the Collaborative Institutional Training Initiative (CITI), a free, comprehensive ethics training program for researchers conducting research with human subjects. Just click on the underlined link.

12. **ADDITIONAL INFORMATION:**

a) If a questionnaire, survey or interview instrument is to be used, attach a copy to this proposal.
Please see attachment D

b) Attach a copy of the informed consent form to this proposal. See the IRB website for a Sample Consent Form and Informed Consent Checklist
http://www.ncsu.edu/sparcs/irb/forms.html
c) Please see attachment C

d) Please provide any additional materials (i.e., recruitment materials, such as "flyers", recruitment scripts, etc.) that may aid the IRB in making its decision.

**If a survey instrument or other documents such as a consent form that will be used in the study are available, attach them to this request. If informed consent is not necessary, an information or fact sheet should be considered in order to provide subjects with information about the study. The informed consent form template on the IRB website could be modified into an information or fact sheet.*

The Following are categories the IRB office uses to determine if your project qualifies for exemption *(a review of the categories below may provide guidance about what sort of information is necessary for the IRB office to verify that your research is exempt)***:**

Exemption Category: *(Choose only one of the following that specifically matches the characteristics of your study that make this project exempt)*

☐ 1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

√ 2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
***Please Note- this exemption for research involving survey or interview procedures or observations of public behavior does not apply to research conducted with minors, except for research that involves observation of public**

behavior when the investigator(s) do not participate in the activities being observed.

☐ 3. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

☐ 4. Research, involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

5. Not applicable

☐ 6. Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration, or approved by the Environmental Protection Agency, or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

APPENDIX D:

IRB APPROVAL:

North Carolina State University is a land-grant university and a constituent institution of the University of North Carolina

Office of Research and Innovation
Division of Research Administration

NC STATE UNIVERSITY

Campus Box 7514
Raleigh, North Carolina 27695-7514

919.515.2444 (phone)
919.515.7721 (fax)

From: Carol Mickelson, IRB Coordinator
North Carolina State University
Institutional Review Board

Date: January 13, 2012

Title: Acceptance of Bast Fiber Fabric Through Subjective Hand Evaluation

IRB#: 2445

Dear Ms. Clare Stanhope and all,

The research proposal named above has received administrative review and has been approved as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.101. b.2). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review.

NOTE:

1. This committee complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU projects, the Assurance Number is: FWA00003429.

2. Any changes to the research must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days.

Please forward a copy of this letter to your faculty sponsor, if applicable. Thank you.

Sincerely,

Carol Mickelson

Carol Mickelson
NC State IRB

North Carolina State University is a land-grant university and a constituent institution of the University of North Carolina

Office of Research and Innovation
Division of Research Administration

NC STATE UNIVERSITY

Campus Box 7514
Raleigh, North Carolina 27695-7514

919.515.2444 (phone)
919.515.7721 (fax)

From: Carol Mickelson, IRB Coordinator
North Carolina State University
Institutional Review Board

Date: March 20, 2012

Title: Acceptance of Bast Fiber Fabric Through Subjective Hand Evaluation

IRB#: 2445

Dear Claire Stanhope,

Your addendum to the study named above has been reviewed and approved by the IRB office. The addendum does not change the original IRB exemption status of this project and you are free to proceed with your study.

If you have any questions please do not hesitate to contact the IRB office at 919.515.4514.

Sincerely,

Carol Mickelson

Carol Mickelson
NC State IRB

APPENDIX E:

RECRUITMENT EMAIL (Undergraduate department):

From: Kent Hester khester@ncsu.edu
Date: Wed, Feb 15t,2012 at 10:22am
Subject: Special Mid-Week Email

Pardon the Interruption...

Below are a few items that just cannot wait until this weekend. Please read and respond or participate where appropriate.

Thanks,
Kent
<Data omitted from email not pertinent to this research>

For All Students...

Claire Stanhope, a COT graduate student, will be conducting physical hand evaluations for her thesis, and she wants people to sign up to participate. All participants will be entered into a raffle to win cool local sustainable prizes including jewelry from local (sustainable) designer, a reusable grocery bag, Magnets, discount coupons, and gift certificates to local stores and more!!

The Survey will take only about 20 minutes per person, and she will be able to test up to 4 people at a time! Exact location of the testing is TBD, and will be included on the sign-up sheet. The sign-up sheet will be posted on the door to the digital design lab and testing will begin next week!

For more information, contact Claire Stanhope at cmstanho@ncsu.edu
Thanks!

RECRUITMENT EMAIL (Graduate Department):

From: Claire Stanhope <cmstanho@ncsu.edu>
Date: Mon, Feb 20, 2012 at 1:50 PM
Subject: Participants for Physical Hand evaluation for Thesis

Hello,

My name is Claire Stanhope and I am conducting physical hand evaluations for my thesis. I need participants to sign up to take my quick fabric hand evaluation survey.

All participants will be entered into a raffle to win cool local sustainable prizes including jewelry from local (sustainable) designer, a reusable grocery bag, magnets, discount coupons, and gift certificates to local stores and more!!
The tests will take only about 20 min per person, and I can test up to 4 people at a time! The testing will take place in room 2203, which is to the right of the stairs off of the atrium.

The Sign-up sheet is located in the digital design lab next to the 3D printer on the door, or email me what time you are available. I will be testing this week and next week.

If you have already participated, please tell your friends!

Your help is greatly appreciated!

Claire Stanhope cmstanho@ncsu.edu

APPENDIX F:

E-MAIL TO PROFESSORS

Purpose: To gain permission to utilize classroom time for student recruiting

Study: Acceptance of bast fiber fabric through subjective hand evaluation

Principal Investigator: Claire Stanhope Faculty Sponsor: Lisa Parrillo-Chapman

Hello,

My name is Claire Stanhope and I am currently conducting my thesis research. The topic of my thesis is sustainable materials for interior product development, and I am specifically focusing my research on bast fiber materials. As my methodology I am hoping to be able to use students to participate in a research procedure that measures the response that the students have to subjective hand testing of bast fiber fabrics compared to other fabrics used in the interior industry.

The results of the procedure will remain anonymous, and students will fill out an informed consent form prior to completing the testing. Students will be informed that the survey has no impact on their grade, and I will offer to discuss the results with them after analysis has been conducted. Please let me know if you would be willing to grant me permission to enter your classroom and recruit students by telling them about what I am doing. This should only take about 5 min. of class time. If you would like to view a sample of the questionnaire, and procedure, I would be more than happy to provide this documentation for you. The procedure should take no longer the 20 min. per student and will be conducted outside of the class period.

Thank you in advance for your consideration.

APPENDIX G:

PERMUTATIONS OF FABRICS ABCDE:

1	ABECD	34	EBADC	67	EDACB
2	EABCD	35	DCEBA	68	BEACD
3	EADCB	36	CADEB	69	BCDEA
4	ABCED	37	DABEC	70	EACDB
5	CBDAE	38	ADECB	71	CEDBA
6	BEDCA	39	CDAEB	72	ACBED
7	EBACD	40	ADEBC	73	ABDCE
8	DAEBC	41	BDCEA	74	BACED
9	DEABC	42	CEBDA	75	DAECB
10	CADBE	43	AEBDC	76	ADCBE
11	DBACE	44	EBDCA	77	DEBCA
12	ACDBE	45	EADBC	78	CABED
13	ECDBA	46	CEDAB	79	BECDA
14	CDBAE	47	BCEAD	80	BAEDC
15	DACEB	48	EBDAC	81	CBEAD
16	DABCE	49	ABEDC	82	BADCE
17	CDBEA	50	DCBEA	83	ECABD
18	AECDB	51	CDABE	84	BCAED
19	CBEDA	52	ADCEB	85	ABDEC
20	DBCAE	53	ECBAD	86	BDECA
21	DBEAC	54	BEDAC	87	BDAEC
22	CEADB	55	BDACE	88	CDEBA
23	DCABE	56	DBECA	89	BDEAC
24	DECBA	57	CDEAB	90	AEDBC
25	CABDE	58	BADEC	91	EDCAB
26	ACEBD	59	ACDEB	92	ACEDB
27	CEABD	60	DBAEC	93	EACBD
28	EDABC	61	EABDC	94	DCEAB
29	CAEBD	62	ACBDE	95	BAECD
30	AECBD	63	BDCAE	96	EBCDA
31	ADBCE	64	BECAD	97	ECDAB
32	AEDCB	65	BCEDA	98	BCDAE
33	EDBCA	66	BCADE	99	EBCAD

100	DECAB	104	ECBDA	107	
101	EDCBA	105	CBDEA	108	DBCEA
102	DEBAC	106	DCAEB		
103	CBADE		DCBAE		
109	EDBAC	114	ECADB	119	CAEDB
110	ABCDE	115	BACDE	120	CBAED
111	BEADC	116	ADBEC		
112	DEACB	117	CEBAD		
113	DACBE	118	AEBCD		

APPENDIX H:

The CORR Procedure

fabric=A

8 Variables:	temp	moisture	texture	hairy	thickness	flex	stretch	comfort

Simple Statistics						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
temp	102	2.98039	0.95420	304.00000	1.00000	5.00000
moisture	102	1.96078	0.65886	200.00000	1.00000	4.00000
texture	102	2.25490	0.71319	230.00000	1.00000	4.00000
hairy	102	3.02941	0.80168	309.00000	1.00000	5.00000
thickness	102	3.11765	0.82407	318.00000	1.00000	5.00000
flex	102	3.62745	0.97414	370.00000	1.00000	5.00000
stretch	102	3.23529	0.96653	330.00000	1.00000	5.00000
comfort	102	2.87255	0.94052	293.00000	1.00000	5.00000

Pearson Correlation Coefficients, N = 102 Prob > |r| under H0: Rho=0								
	temp	moisture	texture	hairy	thickness	flex	stretch	comfort
temp	1.00000	-0.17447	-0.22537	-0.08984	0.35552	-0.07185	-0.08083	-0.06901
		0.0795	0.0228	0.3692	0.0002	0.4730	0.4193	0.4907
moisture	-0.17447	1.00000	0.23219	0.02095	-0.10083	0.19298	0.18566	0.19957
	0.0795		0.0189	0.8344	0.3133	0.0520	0.0617	0.0443
texture	-0.22537	0.23219	1.00000	-0.08251	-0.23684	0.22355	0.17067	0.32936
	0.0228	0.0189		0.4097	0.0165	0.0239	0.0863	0.0007
hairy	-0.08984	0.02095	-0.08251	1.00000	0.06965	-0.08726	0.08043	-0.13942
	0.3692	0.8344	0.4097		0.4867	0.3832	0.4217	0.1622
thickness	0.35552	-0.10083	-0.23684	0.06965	1.00000	-0.40121	-0.19670	-0.18485
	0.0002	0.3133	0.0165	0.4867		<.0001	0.0475	0.0629
flex	-0.07185	0.19298	0.22355	-0.08726	-0.40121	1.00000	0.49362	0.41235
	0.4730	0.0520	0.0239	0.3832	<.0001		<.0001	<.0001
stretch	-0.08083	0.18566	0.17067	0.08043	-0.19670	0.49362	1.00000	0.26204
	0.4193	0.0617	0.0863	0.4217	0.0475	<.0001		0.0078
comfort	-0.06901	0.19957	0.32936	-0.13942	-0.18485	0.41235	0.26204	1.00000
	0.4907	0.0443	0.0007	0.1622	0.0629	<.0001	0.0078	

The CORR Procedure

fabric=B

8 Variables:	temp	moisture	texture	hairy	thickness	flex	stretch	comfort

Simple Statistics						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
temp	102	2.08824	0.79731	213.00000	1.00000	4.00000
moisture	102	2.56863	0.78991	262.00000	1.00000	4.00000
texture	102	3.11765	0.96774	318.00000	1.00000	5.00000
hairy	102	2.49020	0.78027	254.00000	1.00000	4.00000
thickness	102	2.15686	0.75446	220.00000	1.00000	4.00000
flex	102	4.12745	0.87508	421.00000	1.00000	5.00000
stretch	102	3.26471	1.01403	333.00000	1.00000	5.00000
comfort	102	3.57843	0.98941	365.00000	2.00000	5.00000

Pearson Correlation Coefficients, N = 102 Prob > |r| under H0: Rho=0								
	temp	moisture	texture	hairy	thickness	flex	stretch	comfort
temp	1.00000	-0.12762	-0.02642	-0.00655	0.27303	-0.10142	0.04430	-0.04024
		0.2012	0.7921	0.9479	0.0055	0.3104	0.6584	0.6880
moisture	-0.12762	1.00000	0.15771	-0.13544	-0.01824	0.16627	-0.07853	0.13240
	0.2012		0.1134	0.1747	0.8556	0.0949	0.4327	0.1847
texture	-0.02642	0.15771	1.00000	-0.16892	-0.18826	0.36794	0.17983	0.56934
	0.7921	0.1134		0.0897	0.0581	0.0001	0.0705	<.0001
hairy	-0.00655	-0.13544	-0.16892	1.00000	0.22129	-0.03440	0.02208	-0.11442
	0.9479	0.1747	0.0897		0.0254	0.7314	0.8256	0.2522
thickness	0.27303	-0.01824	-0.18826	0.22129	1.00000	-0.12056	-0.14540	-0.24213
	0.0055	0.8556	0.0581	0.0254		0.2274	0.1448	0.0142
flex	-0.10142	0.16627	0.36794	-0.03440	-0.12056	1.00000	0.39676	0.45147
	0.3104	0.0949	0.0001	0.7314	0.2274		<.0001	<.0001
stretch	0.04430	-0.07853	0.17983	0.02208	-0.14540	0.39676	1.00000	0.28009
	0.6584	0.4327	0.0705	0.8256	0.1448	<.0001		0.0044
comfort	-0.04024	0.13240	0.56934	-0.11442	-0.24213	0.45147	0.28009	1.00000
	0.6880	0.1847	<.0001	0.2522	0.0142	<.0001	0.0044	

The CORR Procedure

fabric=C

8 Variables:	temp	moisture	texture	hairy	thickness	flex	stretch	comfort

Simple Statistics						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
temp	102	2.12745	0.84046	217.00000	1.00000	4.00000
moisture	102	2.46078	0.88633	251.00000	1.00000	5.00000
texture	102	2.74510	1.04062	280.00000	1.00000	5.00000
hairy	102	2.86275	0.89042	292.00000	1.00000	5.00000
thickness	102	1.52941	0.72721	156.00000	1.00000	4.00000
flex	102	4.43137	0.63729	452.00000	2.00000	5.00000
stretch	102	3.89216	0.85489	397.00000	1.00000	5.00000
comfort	102	3.62745	1.03332	370.00000	1.00000	5.00000

Pearson Correlation Coefficients, N = 102 Prob > |r| under H0: Rho=0								
	temp	moisture	texture	hairy	thickness	flex	stretch	comfort
temp	1.00000	-0.02645	-0.13230	0.10299	0.37450	-0.08518	-0.15982	-0.16140
		0.7918	0.1850	0.3030	0.0001	0.3947	0.1086	0.1051
moisture	-0.02645	1.00000	0.04273	0.08093	0.12470	0.04777	0.01396	0.14605
	0.7918		0.6698	0.4187	0.2118	0.6335	0.8892	0.1430
texture	-0.13230	0.04273	1.00000	-0.14499	0.02309	0.19731	0.18025	0.48169
	0.1850	0.6698		0.1460	0.8178	0.0468	0.0698	<.0001
hairy	0.10299	0.08093	-0.14499	1.00000	0.08275	0.07048	0.24050	-0.01308
	0.3030	0.4187	0.1460		0.4083	0.4815	0.0149	0.8962
thickness	0.37450	0.12470	0.02309	0.08275	1.00000	-0.04901	-0.03466	0.01473
	0.0001	0.2118	0.8178	0.4083		0.6247	0.7294	0.8832
flex	-0.08518	0.04777	0.19731	0.07048	-0.04901	1.00000	0.43153	0.26149
	0.3947	0.6335	0.0468	0.4815	0.6247		<.0001	0.0079
stretch	-0.15982	0.01396	0.18025	0.24050	-0.03466	0.43153	1.00000	0.12219
	0.1086	0.8892	0.0698	0.0149	0.7294	<.0001		0.2212
comfort	-0.16140	0.14605	0.48169	-0.01308	0.01473	0.26149	0.12219	1.00000
	0.1051	0.1430	<.0001	0.8962	0.8832	0.0079	0.2212	

The CORR Procedure

fabric=D

8 Variables:	temp	moisture	texture	hairy	thickness	flex	stretch	comfort

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Minimum**	**Maximum**
temp	102	2.91176	0.87995	297.00000	1.00000	5.00000
moisture	102	2.34314	0.77709	239.00000	1.00000	4.00000
texture	102	4.10784	0.72994	419.00000	2.00000	5.00000
hairy	102	2.73529	0.97419	279.00000	1.00000	4.00000
thickness	102	2.73529	0.87796	279.00000	1.00000	4.00000
flex	102	4.02941	0.76373	411.00000	1.00000	5.00000
stretch	102	3.56863	0.88452	364.00000	1.00000	5.00000
comfort	102	4.14706	0.65093	423.00000	2.00000	5.00000

Pearson Correlation Coefficients, N = 102 Prob > |r| under H0: Rho=0								
	temp	**moisture**	**texture**	**hairy**	**thickness**	**flex**	**stretch**	**comfort**
temp	1.00000	0.04472	-0.21626	0.38828	0.22578	0.04810	0.12870	-0.23641
		0.6554	0.0290	<.0001	0.0225	0.6312	0.1973	0.0167
moisture	0.04472	1.00000	0.03885	-0.06193	0.11994	-0.11727	-0.02740	0.01670
	0.6554		0.6983	0.5363	0.2299	0.2405	0.7846	0.8677
texture	-0.21626	0.03885	1.00000	-0.30755	-0.17131	0.02977	-0.06525	0.42473
	0.0290	0.6983		0.0017	0.0851	0.7664	0.5147	<.0001
hairy	0.38828	-0.06193	-0.30755	1.00000	0.11406	0.19687	0.22237	-0.10975
	<.0001	0.5363	0.0017		0.2537	0.0473	0.0247	0.2721
thickness	0.22578	0.11994	-0.17131	0.11406	1.00000	-0.18023	-0.18674	-0.22573
	0.0225	0.2299	0.0851	0.2537		0.0699	0.0602	0.0225
flex	0.04810	-0.11727	0.02977	0.19687	-0.18023	1.00000	0.47332	0.38954
	0.6312	0.2405	0.7664	0.0473	0.0699		<.0001	<.0001
stretch	0.12870	-0.02740	-0.06525	0.22237	-0.18674	0.47332	1.00000	0.05968
	0.1973	0.7846	0.5147	0.0247	0.0602	<.0001		0.5513
comfort	-0.23641	0.01670	0.42473	-0.10975	-0.22573	0.38954	0.05968	1.00000
	0.0167	0.8677	<.0001	0.2721	0.0225	<.0001	0.5513	

The CORR Procedure

fabric=E

8 Variables:	temp	moisture	texture	hairy	thickness	flex	stretch	comfort

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
temp	102	2.76471	0.95624	282.00000	1.00000	5.00000
moisture	102	2.43137	0.77727	248.00000	1.00000	4.00000
texture	102	4.12745	0.69896	421.00000	2.00000	5.00000
hairy	102	2.84314	0.99250	290.00000	1.00000	5.00000
thickness	102	2.40196	0.85896	245.00000	1.00000	4.00000
flex	102	4.43137	0.60542	452.00000	2.00000	5.00000
stretch	102	4.42157	0.77634	451.00000	1.00000	5.00000
comfort	102	4.50000	0.65627	459.00000	1.00000	5.00000

Pearson Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	temp	moisture	texture	hairy	thickness	flex	stretch	comfort
temp	1.00000	-0.30168	-0.14726	-0.03927	0.18861	-0.04527	-0.09179	-0.15777
		0.0021	0.1397	0.6951	0.0576	0.6514	0.3588	0.1133
moisture	-0.30168	1.00000	0.06182	0.13992	0.03431	-0.04167	0.12226	-0.07764
	0.0021		0.5371	0.1607	0.7321	0.6775	0.2209	0.4380
texture	-0.14726	0.06182	1.00000	-0.24207	-0.20161	0.19636	0.11896	0.42090
	0.1397	0.5371		0.0142	0.0422	0.0479	0.2337	<.0001
hairy	-0.03927	0.13992	-0.24207	1.00000	0.33020	-0.06753	-0.02898	-0.13681
	0.6951	0.1607	0.0142		0.0007	0.5001	0.7725	0.1703
thickness	0.18861	0.03431	-0.20161	0.33020	1.00000	-0.18442	-0.13785	-0.09660
	0.0576	0.7321	0.0422	0.0007		0.0635	0.1671	0.3341
flex	-0.04527	-0.04167	0.19636	-0.06753	-0.18442	1.00000	0.36761	0.32395
	0.6514	0.6775	0.0479	0.5001	0.0635		0.0001	0.0009
stretch	-0.09179	0.12226	0.11896	-0.02898	-0.13785	0.36761	1.00000	0.24292
	0.3588	0.2209	0.2337	0.7725	0.1671	0.0001		0.0139
comfort	-0.15777	-0.07764	0.42090	-0.13681	-0.09660	0.32395	0.24292	1.00000
	0.1133	0.4380	<.0001	0.1703	0.3341	0.0009	0.0139	

The SUMMARY Procedure

fabric=A

Variable	Mean	Median
temp	2.9803922	3.0000000
moisture	1.9607843	2.0000000
texture	2.2549020	2.0000000
hairy	3.0294118	3.0000000
thickness	3.1176471	3.0000000
flex	3.6274510	4.0000000
stretch	3.2352941	4.0000000
comfort	2.8725490	3.0000000

fabric=B

Variable	Mean	Median
temp	2.0882353	2.0000000
moisture	2.5686275	2.0000000
texture	3.1176471	3.0000000
hairy	2.4901961	2.0000000
thickness	2.1568627	2.0000000
flex	4.1274510	4.0000000
stretch	3.2647059	4.0000000
comfort	3.5784314	4.0000000

fabric=C

Variable	Mean	Median
temp	2.1274510	2.0000000
moisture	2.4607843	2.0000000
texture	2.7450980	2.0000000
hairy	2.8627451	3.0000000
thickness	1.5294118	1.0000000
flex	4.4313725	4.0000000
stretch	3.8921569	4.0000000
comfort	3.6274510	4.0000000

fabric=D

Variable	Mean	Median
temp	2.9117647	3.0000000
moisture	2.3431373	2.0000000
texture	4.1078431	4.0000000
hairy	2.7352941	3.0000000
thickness	2.7352941	3.0000000
flex	4.0294118	4.0000000
stretch	3.5686275	4.0000000
comfort	4.1470588	4.0000000

fabric=E

Variable	Mean	Median
temp	2.7647059	3.0000000
moisture	2.4313725	2.0000000
texture	4.1274510	4.0000000
hairy	2.8431373	3.0000000
thickness	2.4019608	2.0000000
flex	4.4313725	4.0000000
stretch	4.4215686	5.0000000
comfort	4.5000000	5.0000000

The TTEST Procedure

Variable: comfort

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	3.6029	1.0094	0.0707	1.0000	5.0000
nonb	204	4.3235	0.6756	0.0473	1.0000	5.0000
Diff (1-2)		-0.7206	0.8589	0.0850		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		3.6029	3.4636	3.7423	1.0094	0.9200	1.1182
nonb		4.3235	4.2303	4.4168	0.6756	0.6158	0.7483
Diff (1-2)	Pooled	-0.7206	-0.8878	-0.5534	0.8589	0.8036	0.9223
Diff (1-2)	Satterthwaite	-0.7206	-0.8878	-0.5533			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	-8.47	<.0001
Satterthwaite	Unequal	354.47	-8.47	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	2.23	<.0001

Variable: comfort

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	3.5784	0.9894	0.0980	2.0000	5.0000
C	102	3.6275	1.0333	0.1023	1.0000	5.0000
Diff (1-2)		-0.0490	1.0116	0.1417		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		3.5784	3.3841	3.7728	0.9894	0.8698	1.1475
C		3.6275	3.4245	3.8304	1.0333	0.9084	1.1985
Diff (1-2)	Pooled	-0.0490	-0.3283	0.2303	1.0116	0.9218	1.1209
Diff (1-2)	Satterthwaite	-0.0490	-0.3283	0.2303			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-0.35	0.7297
Satterthwaite	Unequal	201.62	-0.35	0.7297

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.09	0.6634

Variable: comfort

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	4.1471	0.6509	0.0645	2.0000	5.0000
E	102	4.5000	0.6563	0.0650	1.0000	5.0000
Diff (1-2)		-0.3529	0.6536	0.0915		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		4.1471	4.0192	4.2749	0.6509	0.5722	0.7550
E		4.5000	4.3711	4.6289	0.6563	0.5769	0.7612
Diff (1-2)	Pooled	-0.3529	-0.5334	-0.1725	0.6536	0.5956	0.7242
Diff (1-2)	Satterthwaite	-0.3529	-0.5334	-0.1725			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-3.86	0.0002
Satterthwaite	Unequal	201.99	-3.86	0.0002

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.02	0.9346

Variable: temp

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	2.1078	0.8174	0.0572	1.0000	4.0000
nonb	204	2.8382	0.9196	0.0644	1.0000	5.0000
Diff (1-2)		-0.7304	0.8700	0.0861		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		2.1078	1.9950	2.2207	0.8174	0.7450	0.9054
nonb		2.8382	2.7113	2.9652	0.9196	0.8382	1.0186
Diff (1-2)	Pooled	-0.7304	-0.8997	-0.5611	0.8700	0.8140	0.9342
Diff (1-2)	Satterthwaite	-0.7304	-0.8997	-0.5610			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	-8.48	<.0001
Satterthwaite	Unequal	400.49	-8.48	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	1.27	0.0940

Variable: temp

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	2.0882	0.7973	0.0789	1.0000	4.0000
C	102	2.1275	0.8405	0.0832	1.0000	4.0000
Diff (1-2)		-0.0392	0.8192	0.1147		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		2.0882	1.9316	2.2448	0.7973	0.7009	0.9247
C		2.1275	1.9624	2.2925	0.8405	0.7388	0.9748
Diff (1-2)	Pooled	-0.0392	-0.2654	0.1870	0.8192	0.7465	0.9077
Diff (1-2)	Satterthwaite	-0.0392	-0.2654	0.1870			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-0.34	0.7328
Satterthwaite	Unequal	201.44	-0.34	0.7328

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.11	0.5973

Variable: temp

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	2.9118	0.8800	0.0871	1.0000	5.0000
E	102	2.7647	0.9562	0.0947	1.0000	5.0000
Diff (1-2)		0.1471	0.9189	0.1287		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		2.9118	2.7389	3.0846	0.8800	0.7735	1.0206
E		2.7647	2.5769	2.9525	0.9562	0.8406	1.1091
Diff (1-2)	Pooled	0.1471	-0.1066	0.4008	0.9189	0.8374	1.0181
Diff (1-2)	Satterthwaite	0.1471	-0.1067	0.4008			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	1.14	0.2544
Satterthwaite	Unequal	200.62	1.14	0.2544

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.18	0.4049

Variable: moisture

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	2.5147	0.8392	0.0588	1.0000	5.0000
nonb	204	2.3873	0.7765	0.0544	1.0000	4.0000
Diff (1-2)		0.1275	0.8085	0.0800		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		2.5147	2.3989	2.6306	0.8392	0.7649	0.9296
nonb		2.3873	2.2801	2.4945	0.7765	0.7078	0.8602
Diff (1-2)	Pooled	0.1275	-0.0299	0.2848	0.8085	0.7565	0.8682
Diff (1-2)	Satterthwaite	0.1275	-0.0299	0.2848			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	1.59	0.1121
Satterthwaite	Unequal	403.58	1.59	0.1121

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	1.17	0.2698

Variable: moisture

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	2.5686	0.7899	0.0782	1.0000	4.0000
C	102	2.4608	0.8863	0.0878	1.0000	5.0000
Diff (1-2)		0.1078	0.8395	0.1176		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		2.5686	2.4135	2.7238	0.7899	0.6944	0.9161
C		2.4608	2.2867	2.6349	0.8863	0.7791	1.0280
Diff (1-2)	Pooled	0.1078	-0.1239	0.3396	0.8395	0.7650	0.9302
Diff (1-2)	Satterthwaite	0.1078	-0.1240	0.3397			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	0.92	0.3600
Satterthwaite	Unequal	199.38	0.92	0.3600

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.26	0.2488

Variable: moisture

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	2.3431	0.7771	0.0769	1.0000	4.0000
E	102	2.4314	0.7773	0.0770	1.0000	4.0000
Diff (1-2)		-0.0882	0.7772	0.1088		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		2.3431	2.1905	2.4958	0.7771	0.6831	0.9013
E		2.4314	2.2787	2.5840	0.7773	0.6833	0.9015
Diff (1-2)	Pooled	-0.0882	-0.3028	0.1263	0.7772	0.7082	0.8611
Diff (1-2)	Satterthwaite	-0.0882	-0.3028	0.1263			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-0.81	0.4184
Satterthwaite	Unequal	202	-0.81	0.4184

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.00	0.9981

Variable: texture

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	2.9314	1.0196	0.0714	1.0000	5.0000
nonb	204	4.1176	0.7129	0.0499	2.0000	5.0000
Diff (1-2)		-1.1863	0.8797	0.0871		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		2.9314	2.7906	3.0721	1.0196	0.9293	1.1295
nonb		4.1176	4.0192	4.2161	0.7129	0.6498	0.7897
Diff (1-2)	Pooled	-1.1863	-1.3575	-1.0150	0.8797	0.8232	0.9447
Diff (1-2)	Satterthwaite	-1.1863	-1.3576	-1.0150			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	-13.62	<.0001
Satterthwaite	Unequal	363.2	-13.62	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	2.05	<.0001

Variable: texture

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	3.1176	0.9677	0.0958	1.0000	5.0000
C	102	2.7451	1.0406	0.1030	1.0000	5.0000
Diff (1-2)		0.3725	1.0048	0.1407		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		3.1176	2.9276	3.3077	0.9677	0.8507	1.1224
C		2.7451	2.5407	2.9495	1.0406	0.9148	1.2069
Diff (1-2)	Pooled	0.3725	0.0951	0.6500	1.0048	0.9157	1.1134
Diff (1-2)	Satterthwaite	0.3725	0.0951	0.6500			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	2.65	0.0087
Satterthwaite	Unequal	200.94	2.65	0.0087

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.16	0.4668

Variable: texture

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	4.1078	0.7299	0.0723	2.0000	5.0000
E	102	4.1275	0.6990	0.0692	2.0000	5.0000
Diff (1-2)		-0.0196	0.7146	0.1001		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		4.1078	3.9645	4.2512	0.7299	0.6417	0.8466
E		4.1275	3.9902	4.2647	0.6990	0.6144	0.8107
Diff (1-2)	Pooled	-0.0196	-0.2169	0.1777	0.7146	0.6512	0.7918
Diff (1-2)	Satterthwaite	-0.0196	-0.2169	0.1777			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-0.20	0.8448
Satterthwaite	Unequal	201.62	-0.20	0.8448

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.09	0.6638

Variable: hairy

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	2.6765	0.8557	0.0599	1.0000	5.0000
nonb	204	2.7892	0.9824	0.0688	1.0000	5.0000
Diff (1-2)		-0.1127	0.9213	0.0912		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		2.6765	2.5583	2.7946	0.8557	0.7800	0.9479
nonb		2.7892	2.6536	2.9248	0.9824	0.8955	1.0883
Diff (1-2)	Pooled	-0.1127	-0.2921	0.0666	0.9213	0.8620	0.9893
Diff (1-2)	Satterthwaite	-0.1127	-0.2921	0.0666			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	-1.24	0.2172
Satterthwaite	Unequal	398.49	-1.24	0.2172

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	1.32	0.0497

Variable: hairy

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	2.4902	0.7803	0.0773	1.0000	4.0000
C	102	2.8627	0.8904	0.0882	1.0000	5.0000
Diff (1-2)		-0.3725	0.8372	0.1172		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		2.4902	2.3369	2.6435	0.7803	0.6859	0.9050
C		2.8627	2.6878	3.0376	0.8904	0.7827	1.0327
Diff (1-2)	Pooled	-0.3725	-0.6037	-0.1414	0.8372	0.7629	0.9276
Diff (1-2)	Satterthwaite	-0.3725	-0.6037	-0.1414			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-3.18	0.0017
Satterthwaite	Unequal	198.58	-3.18	0.0017

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.30	0.1862

Variable: hairy

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	2.7353	0.9742	0.0965	1.0000	4.0000
E	102	2.8431	0.9925	0.0983	1.0000	5.0000
Diff (1-2)		-0.1078	0.9834	0.1377		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		2.7353	2.5439	2.9266	0.9742	0.8564	1.1299
E		2.8431	2.6482	3.0381	0.9925	0.8725	1.1511
Diff (1-2)	Pooled	-0.1078	-0.3794	0.1637	0.9834	0.8961	1.0896
Diff (1-2)	Satterthwaite	-0.1078	-0.3794	0.1637			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-0.78	0.4344
Satterthwaite	Unequal	201.93	-0.78	0.4344

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.04	0.8519

Variable: thickness

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	1.8431	0.8033	0.0562	1.0000	4.0000
nonb	204	2.5686	0.8823	0.0618	1.0000	4.0000
Diff (1-2)		-0.7255	0.8437	0.0835		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		1.8431	1.7322	1.9540	0.8033	0.7321	0.8898
nonb		2.5686	2.4468	2.6904	0.8823	0.8042	0.9774
Diff (1-2)	Pooled	-0.7255	-0.8897	-0.5613	0.8437	0.7895	0.9060
Diff (1-2)	Satterthwaite	-0.7255	-0.8897	-0.5613			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	-8.68	<.0001
Satterthwaite	Unequal	402.47	-8.68	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	1.21	0.1818

Variable: thickness

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	2.1569	0.7545	0.0747	1.0000	4.0000
C	102	1.5294	0.7272	0.0720	1.0000	4.0000
Diff (1-2)		0.6275	0.7410	0.1038		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		2.1569	2.0087	2.3051	0.7545	0.6632	0.8750
C		1.5294	1.3866	1.6722	0.7272	0.6393	0.8434
Diff (1-2)	Pooled	0.6275	0.4229	0.8320	0.7410	0.6752	0.8210
Diff (1-2)	Satterthwaite	0.6275	0.4229	0.8320			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	6.05	<.0001
Satterthwaite	Unequal	201.73	6.05	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.08	0.7123

Variable: thickness

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	2.7353	0.8780	0.0869	1.0000	4.0000
E	102	2.4020	0.8590	0.0851	1.0000	4.0000
Diff (1-2)		0.3333	0.8685	0.1216		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		2.7353	2.5628	2.9077	0.8780	0.7718	1.0183
E		2.4020	2.2332	2.5707	0.8590	0.7551	0.9962
Diff (1-2)	Pooled	0.3333	0.0935	0.5731	0.8685	0.7915	0.9623
Diff (1-2)	Satterthwaite	0.3333	0.0935	0.5731			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	2.74	0.0067
Satterthwaite	Unequal	201.9	2.74	0.0067

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.04	0.8264

Variable: flex

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	4.2794	0.7786	0.0545	1.0000	5.0000
nonb	204	4.2304	0.7164	0.0502	1.0000	5.0000
Diff (1-2)		0.0490	0.7481	0.0741		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		4.2794	4.1719	4.3869	0.7786	0.7097	0.8625
nonb		4.2304	4.1315	4.3293	0.7164	0.6529	0.7935
Diff (1-2)	Pooled	0.0490	-0.0966	0.1946	0.7481	0.7000	0.8034
Diff (1-2)	Satterthwaite	0.0490	-0.0966	0.1946			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	0.66	0.5085
Satterthwaite	Unequal	403.21	0.66	0.5085

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	1.18	0.2357

Variable: flex

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	4.1275	0.8751	0.0866	1.0000	5.0000
C	102	4.4314	0.6373	0.0631	2.0000	5.0000
Diff (1-2)		-0.3039	0.7655	0.1072		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		4.1275	3.9556	4.2993	0.8751	0.7693	1.0149
C		4.4314	4.3062	4.5565	0.6373	0.5602	0.7391
Diff (1-2)	Pooled	-0.3039	-0.5153	-0.0926	0.7655	0.6976	0.8482
Diff (1-2)	Satterthwaite	-0.3039	-0.5154	-0.0925			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-2.84	0.0050
Satterthwaite	Unequal	184.61	-2.84	0.0051

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.89	0.0016

Variable: flex

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	4.0294	0.7637	0.0756	1.0000	5.0000
E	102	4.4314	0.6054	0.0599	2.0000	5.0000
Diff (1-2)		-0.4020	0.6891	0.0965		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		4.0294	3.8794	4.1794	0.7637	0.6714	0.8858
E		4.4314	4.3125	4.5503	0.6054	0.5322	0.7022
Diff (1-2)	Pooled	-0.4020	-0.5922	-0.2117	0.6891	0.6280	0.7636
Diff (1-2)	Satterthwaite	-0.4020	-0.5923	-0.2116			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-4.17	<.0001
Satterthwaite	Unequal	192	-4.17	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.59	0.0204

Variable: stretch

type	N	Mean	Std Dev	Std Err	Minimum	Maximum
bast	204	3.5784	0.9870	0.0691	1.0000	5.0000
nonb	204	3.9951	0.9338	0.0654	1.0000	5.0000
Diff (1-2)		-0.4167	0.9607	0.0951		

type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
bast		3.5784	3.4422	3.7147	0.9870	0.8996	1.0933
nonb		3.9951	3.8662	4.1240	0.9338	0.8511	1.0343
Diff (1-2)	Pooled	-0.4167	-0.6037	-0.2297	0.9607	0.8990	1.0317
Diff (1-2)	Satterthwaite	-0.4167	-0.6037	-0.2297			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	406	-4.38	<.0001
Satterthwaite	Unequal	404.76	-4.38	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	203	203	1.12	0.4304

Variable: stretch

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
B	102	3.2647	1.0140	0.1004	1.0000	5.0000
C	102	3.8922	0.8549	0.0846	1.0000	5.0000
Diff (1-2)		-0.6275	0.9378	0.1313		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
B		3.2647	3.0655	3.4639	1.0140	0.8914	1.1761
C		3.8922	3.7242	4.0601	0.8549	0.7515	0.9915
Diff (1-2)	Pooled	-0.6275	-0.8864	-0.3685	0.9378	0.8546	1.0391
Diff (1-2)	Satterthwaite	-0.6275	-0.8864	-0.3685			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-4.78	<.0001
Satterthwaite	Unequal	196.39	-4.78	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.41	0.0878

Variable: stretch

fabric	N	Mean	Std Dev	Std Err	Minimum	Maximum
D	102	3.5686	0.8845	0.0876	1.0000	5.0000
E	102	4.4216	0.7763	0.0769	1.0000	5.0000
Diff (1-2)		-0.8529	0.8322	0.1165		

fabric	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
D		3.5686	3.3949	3.7424	0.8845	0.7776	1.0259
E		4.4216	4.2691	4.5741	0.7763	0.6825	0.9004
Diff (1-2)	Pooled	-0.8529	-1.0827	-0.6232	0.8322	0.7583	0.9221
Diff (1-2)	Satterthwaite	-0.8529	-1.0827	-0.6231			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	202	-7.32	<.0001
Satterthwaite	Unequal	198.66	-7.32	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	101	101	1.30	0.1916

The FREQ Procedure

Table of fabric by rank							
		rank					
		1	2	3	4	5	Total
fabric							
A	Frequency	0	1	6	13	82	102
	Percent	0.00	0.20	1.18	2.55	16.08	20.00
B	Frequency	8	13	47	30	4	102
	Percent	1.57	2.55	9.22	5.88	0.78	20.00
C	Frequency	7	11	29	41	14	102
	Percent	1.37	2.16	5.69	8.04	2.75	20.00
D	Frequency	29	47	9	16	1	102
	Percent	5.69	9.22	1.76	3.14	0.20	20.00
E	Frequency	58	30	11	2	1	102
	Percent	11.37	5.88	2.16	0.39	0.20	20.00
Total	Frequency	102	102	102	102	102	510
	Percent	20.00	20.00	20.00	20.00	20.00	100.00

The GLM Procedure

Class Level Information		
Class	Levels	Values
fabric	5	A B C D E
ID	102	1 10 11 12 13 14 15 16 17 18 19 2 20 21 22 23 24 25 26 27 28 29 3 30 31 32 33 34 35 36 37 38 39 4 40 41 42 43 44 45 46 47 48 49 5 50 51 52 53 54 55 56 57 58 59 6 60 61 62 63 64 65 66 67 68 69 7 70 71 72 73 74 75 76 8 9 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Number of Observations Read	510
Number of Observations Used	510

Dependent Variable: rank

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	105	595.352941	5.670028	5.39	<.0001
Error	404	424.647059	1.051107		
Corrected Total	509	1020.000000			

R-Square	Coeff Var	Root MSE	rank Mean
0.583679	34.17450	1.025235	3.000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
fabric	4	595.3529412	148.8382353	141.60	<.0001
ID	101	0.0000000	0.0000000	0.00	1.0000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
fabric	4	595.3529412	148.8382353	141.60	<.0001
ID	101	0.0000000	0.0000000	0.00	1.0000

The GLM Procedure

Class Level Information		
Class	Levels	Values
fabric	5	A B C D E
gender	2	0 1
race	5	1 2 3 5 6

Number of Observations Read	510
Number of Observations Used	510

Dependent Variable: comfort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	272.1054253	17.0065891	31.43	<.0001
Error	493	266.7573198	0.5410899		
Corrected Total	509	538.8627451			

R-Square	Coeff Var	Root MSE	comfort Mean
0.504962	19.64136	0.735588	3.745098

Source	DF	Type I SS	Mean Square	F Value	Pr > F
fabric	4	156.5098039	39.1274510	72.31	<.0001
gender	1	1.2563959	1.2563959	2.32	0.1282
race	4	2.4113248	0.6028312	1.11	0.3491
temp	1	5.3290685	5.3290685	9.85	0.0018
moisture	1	2.7300689	2.7300689	5.05	0.0251
texture	1	76.1601734	76.1601734	140.75	<.0001
hairy	1	0.0000150	0.0000150	0.00	0.9958
thickness	1	1.3766250	1.3766250	2.54	0.1113
flex	1	25.8861781	25.8861781	47.84	<.0001
stretch	1	0.4457719	0.4457719	0.82	0.3645

Source	DF	Type III SS	Mean Square	F Value	Pr > F
fabric	4	10.66009162	2.66502291	4.93	0.0007
gender	1	0.20818944	0.20818944	0.38	0.5354
race	4	2.53833176	0.63458294	1.17	0.3219
temp	1	0.64285261	0.64285261	1.19	0.2763
moisture	1	0.70541960	0.70541960	1.30	0.2541
texture	1	50.67888211	50.67888211	93.66	<.0001
hairy	1	0.16040458	0.16040458	0.30	0.5864
thickness	1	0.03342211	0.03342211	0.06	0.8038
flex	1	19.23549287	19.23549287	35.55	<.0001
stretch	1	0.44577186	0.44577186	0.82	0.3645