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Research Article

# The Impact of Blending Wool-Modal Fibers on the Properties of Fabrics Produced at Varying Yarn Counts

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## Abstract

In this study, the effect of various modal: wool blend ratios on yarn count and plain weave fabric parameters are analyzed. The blends analyzed consist of 100% wool, 70: Seven fabrics were prepared using wool-modal, 50:50 wool-modal, 30:70 wool-modal and 100% modal blended yarns with three counts, 20 Ne, 30 Ne and 40 Ne each. The aim is to assess properties of fabric including but not limited to stretchiness, tensile strength, elongation and air permeability and, if so, how adjusted blend and yarn count might impact the result. The results of research reveal that performance of fabric gives dissimilar outcomes depending on wo/ modal ratio. Fabrics produced from 50: The 50; 70 blends had shown higher tensile strength and air permeability than those fabrics fabricated from 100% wool or modal. Notably, the 70: Another interesting feature of 30 blend was that the optimum balance of softness and strength was attained, and it was ideal for application areas that require both properties, to the maximum extent. However, the degree of fabric irregularity came out to be highly dependent on yarn count; the finer yarn-count fabrics (30 Ne & 40 Ne yarn-count) also had low irregularity and high elongation. In the light of the above findings, it is concluded that both blend ratio and yarn count should be well needed to achieve the required fabric properties. This work offers significant recommendations to the textile industry, especially to those producers interested in developing fabrics based on wool and models having the mentioned benefits. Finally, this study helps to progress the development of eco-friendly textile options relevant to the apparel and fashion industries' many sectors, including garments and fabrics. The purpose for undertaking this study was to assess fabric variations as resulting from changes in blend ratios and thread counts with the aim of establishing the optimum blend and thread count combination to produce fabrics with certain stipulated indicators like softness, strength and air permeability desirable in a particular application.

## Keywords

Wool-Modal Blend, Fabric Performance, Air Permeability, Textile Sustainability, Blend Ratio

## 1. Introduction

The textile industry has always been looking for how best to incorporate natural fiber properties with synthetic or semisynthetic fibers to develop high performance fabrics to satisfy base consumer demands. Wool and modal are two such fibers, which in their pure state, possess properties that when combined in the fabrics, have the potential to be improved. Still, wool, or natural material obtained from the fleece of a sheep is still highly valued for its functions like insulation, moisture absorption, much like its synthetic counterpart, flexibility. Such characteristics make wool fit to produce winter wear, sport

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wears and any other wear that requires high performance. But wool can also be voluminous, heavy, shrinkable and often needs to be cared for with much attention. Modal, on the other hand, is a semi-synthetic fiber obtained from beech wood Pulp. Shaeer silk is known for its fine plushness, breathability and it is produced using environmentally friendly method. Modal fibers are more powerful and flexible than cotton and do not shrink easily and offer better absorption qualities which makes it suitable for producing garments that should be comfortable and long-lasting. [1, 2].

Here, the synergistic combination of wool and modal allows for the biggest benefits of each fiber to be realized while at least possibly offsetting some of the indignities of each as well. For instance, modal returns a smooth and silky finish to wool and on the same note, wool can support the thermal support that modal does not offer. This combination may create materials that are soft and comfortable but that also have superior dimensional stability, good air permeability, and thermal properties, making them suitable for use in fashion clothing and in a variety of technical applications such as athletic wear and protective clothing. [3, 5].

The wool-modal also provides a good sustainability proposition for consumers as well. Wool is a renewable resource and naturally biodegradable; the ecological cost of producing wool fabric is relatively low in comparison with the synthetic fabric like polyester. Modal though an S fabric, is obtained from beech tree source that is renewable as well; its manufacturing does not require much water and uses fewer chemicals than those used in the manufacturing of other fibers. Regarding sustainability, wool-modal blends might be an answer to meeting consumer's expectations as they rise for environmentally friendly fabrics. [2, 4].

However, although the advantages of wool-modal blends are quite clear, there is the necessity for additional investigations regarding the influence of the content of these fibers and the yarn count on the performance characteristics of the fabric. Other properties like yarn count, drape, absorbency, thermal inertia, and overall wear become relevant and require further study to determine the best blend suitable for uses. Also, the relationship between wool-modal blend in relation to the yarn count by the 20 s 30 s and 40 s and the propensity to perform ae some fabrics perform better in certain applications by tweaking the yarn count [6, 7]. There is a lack of scientific research found in the library which distinguishes between wool and modal and there is research which is confusing between wool and acrylic as well as modal and cotton.

## 2. Research Problem

Thus, the problem of developing textile materials that would meet specific performance requirements for practical applications while maintaining comfort and being environmentally friendly remains a critical issue for the textile industry. Wool offers good thermal value and dimensional stability but may be too heavy and shrink easily when washed, modal on the other hand is light and silky but offer little insulation or stretch. The problem is in how various yarn counts and blend ratios of wool and modal in a fabric influences its comfort, durability and its impact on the environment.

## 3. Research Aim

1) Analyze the characteristics of the properties of the wool-modal blend yarns.
2) Examine how yarn count affects the fabric characteristics of softness, breathability, and moisture management and product durability.

## 4. Research Importance

1) Examines the potential of wool-modal blend fabrics, where strengths in both fibers are combined.
2) Provides insight into the effect of yarn count and blend ratio on fabric performance, comfort, and durability.
3) This contributes to the demand for green, environmentally friendly textile solutions by evaluating the environmental consequences of wool-modal blends.
4) Helps manufacturers to develop fabrics which are of high performance, eco-friendly, and that can replace more conventional materials.

## 5. Research Hypothesis

1) Primary Hypothesis:
   a) $H_0$: Wool-modal blend fabrics show that yarn count and blend ratio do not have any relationship with the fabric handle, air permeability, moisture transmission, pilling and shrinkage properties of fabrics.
   b) $H_1$: Preliminary findings demonstrate that yarn count and blend ratio exert a strong influence on the softness, breathability, moisture absorption, abrasive strength, and shrinkage resistance of wool-modal blend fabrics.
2) Secondary Hypothesis:
   a) $H_0$: Combing and comparing the properties of wool-modal blend fabrics, it was not found that characteristics were superior to wool fabric or modal fabric in terms of softness, breathability, moisture absorbency, and abrasion and dimensional stability.
   b) $H_1$: The result indicates that blending of wool-modal exhibits higher values of softness, breathability, moisture absorption, wear resistance, and shrinkage resistance than the pure wool fabric as well as the pure modal fabric.

## 6. Literature Review

This approach is well known in the specialty textile industry where the fibers are blended in order to take advantage of the properties of the constituent fibers. Wool and other types of fabric, especially, has gained attention in view of its characteristics and unlike other kinds of fabric, modal has prospects in terms of blending. The recent past research on wool-modal blends provides information on the above depending on the mode of use.

Wool is one of the most investigated and possibly the best in terms of thermal conductivity and moisture control. also pointed out that wool fabric has crimped structures that are effective in the creation of thermal insulating air pockets. This makes it perfect for use in manufacturing clothes that are to be used in cold climates. In addition to that, wool fibers can hold up to thirty percent of their weight in water, which also gives it the capacity of pulling moisture away from the skin and help in the regulation of temperature. This is explained by the fact that; wool has inherent elastic and reconstructive properties Bouton, 2018 and Zhang & Wang, 2020 also found its ability to fight wrinkles and to maintain the shape. Of course, wool has its drawbacks, such as shrinkage and weight, which can be unimpressive for some uses. [7-9]

Modal, regenerated fiber made from beechwood pulp is described as soft and smooth to touch and has an ecological approach to fabrication. Comparison indicates that modal has a higher moisture absorption rate than cotton; therefore, it is appropriate for activewear and sleepwear. The advantage of modal is its non-shrinkage nature as well as the property to maintain bright coloring after several washes. In contrast to synthetic fibers including polyester, modal manufacturing requires relatively less chemical and water, which makes it an environmentally friendly fabric. However, modal does not afford the thermal regulating capability of wool and might not be as warm in colder caption applications. [1, 10, 11]

Modal is a type of modified rayon fiber derived from the pulp of beech trees. It's made from cellulose fibers, which come from plants (other cellulose fibers include linen and hemp). The modal production is like that of viscose (another semisynthetic rayon fiber), except there are more steps and chemicals involved. It begins when a beechwood tree is chopped, chipped, and broken down into a pulp. The cellulose is made into sheets, then soaked in sodium hydroxide bath to create cellulose xanthate- aka viscose. After a second bath, the now liquid solution is pushed through an extruder to produce fibers. The fibers are then placed in a third and final sulphury acid bath, which results in the yarn used to create modal fabric. [2, 13]

Wool and modal blend brings the benefits of wool being insulated and elastic and benefits of modal that is being soft and skin friendly. According to recent studies, wool-modal blends show promising results in improving fabric comfort and functionality. And found that the blend enhances fabric softness and drape, making it suitable for high-end fashion garments. The inclusion of modal in wool blends also improves fabric breathability, as modal helps regulate moisture and prevents overheating. wool-modal blends offer improved durability compared to pure wool, with modal's resistance to shrinkage and strength in wet conditions contributing to the blend's longevity. However, the blend's overall performance depends on the yarn count and the ratio of wool to modal, with varying results for softness, durability, and moisture management based on these factors. [3, 12].

The sustainability of wool-modal blends has incited quite some interest in innovation. Wool is eco-friendly or biodegradable natural fiber; it is also renewable hence, matches the current trends of sustainable textiles. Modal which derived from wood pulp and is considered as an eco-friendlier material compared to synthetic fiber however its manufacturing involves some chemical process. The effects of wool-modal blends revealed the minutest carbon emission in comparison to the synthetic fabrics. If the two blends are produced sustainably, then they can be good environmentally friendly products for textile industries. [15, 16]

The literature also assures that each of the two fibers, wool and modal has some benefits that can be utilized when blended. Wool has the properties of thermal insulation, moisture control and being durable while modal adds softness, moisture absorbent and is eco-friendly. The integration of these two fibers can produce fabric constructions with the ability to meet consumer expectations in comfort, durability, and sustainable uses. That said, current information on the performance characteristics of wool-modal blends is still insufficient and limited to outright factual findings, and more comprehensive research is still required to reveal the interrelationship between yarn count, blend ratio, and processing techniques to fine-tune wool-modal blends to match a particular application. [14, 17].

## 7. Methodology

This section provides a detailed explanation of the research methodology, including the materials, fabric production processes, testing procedures, data collection methods, and analysis techniques. The aim is to systematically evaluate the performance of wool-modal blend fabrics in comparison to pure wool and pure modal fabrics.

### 7.1. Materials

#### 7.1.1. Properties and Characteristics of Wool

Wool refers to an ethic cloth material that is naturally derived and renowned for special characteristics that qualify it for diverse textile uses. It has some remarkable characteristics like thermal insulation, because of natural crimping effects to lock-air in, and serves as insulating layer for the body temperature irrespective of the rainy climate. It can soak up to 30% of its weight and still be dry to the touch, thus is very good in moisture transfer and the wearer can be very comfortable in different types of climates. They also have good elasticity; the fibers regain themselves after being stretched; this lint is also less compressible, more wrinkle resistant, and long-lasting.

Wool fabrics are easy to wear, and among the fine wool fabrics is the Merino which feels good on the skin, skin. Wool is lightweight, porous and does not trap heat making it perfect for today's activewear. Also, wool does not readily accumulate bacterial smell because it has been natural antibacterial and ensuing free radical resistant effect from the lanolin. Wool is also flame resistant and therefore can be used in making protective clothing. Environmental friendliness is another strong positive attribute since wool is biodegradable and its creation entails a lesser amount of ecological pollution as compared with synthetic material.

Nevertheless, it has heat and agitation shrinking which is not good for the wool it requires proper care. Most wool fabrics should not be washed using chemicals because it harms the fabric and proper storage to avoid insect attack. All in all, wool has advocated the principles of insulation, elasticity, softness, and its environmentally friendly factor making it crucial in manufacture of textiles.

#### 7.1.2. Merino Wool

Merino wool is the material used to develop merino wool fabric, and it is a natural fabric which is warm that can be used in almost every style. Therefore, merino wool is very silk like and smooth against the skin due to the process of evolution and selective breeding making it an excellent material for any project. This is the dub of a famous fabric that is used to make everything from comfortable warm sweaters to very sheer wool blouses and even delicate wool lace.

#### 7.1.3. Properties and Characteristics of Modal

Modal is a semi-artificial fiber that comes from beech wood pulp, with characteristics of fineness and smoothness, often compared to silk. It has good moisture absorption and can hold up to more moisture compared to cotton, which makes it good for sportswear, sleepwear, and inner wear. Its breathability provides comfort during summer or sports, as the skin remains dry by drawing away moisture from the body.

Modal is durable and stronger than cotton, especially when wet, and resistant to shrinkage; it retains its size and appearance even after repeated washing. It also has color retention properties, with bright colors that do not fade quickly. Another key advantage of modal is its smooth drapability, enhancing the aesthetic quality of garments and making it suitable for high-end fashion items and dresses.

While modal is more eco-friendly than most synthetic fibers, its production process still has some environmental concerns because it involves chemicals to extract cellulose from wood. However, new and more environmentally friendly manufacturing methods are being developed. It remains strong, moisture-wicking, and an environmentally conscious alternative to other fibers, combining the best qualities of both natural and synthetic materials. Table 1 shows a comparison of the properties and characteristics between Wool and Modal, Table 2 Standard fiber lengths for modal and Merino wool.

***Table 1.*** *Comparison of the properties and characteristics of Wool and Modal.*

| Property/Characteristic | Wool | Modal |
|---|---|---|
| Source | Natural fiber from sheep | Semi-synthetic fiber from beechwood pulp |
| Softness | Soft, especially fine grades like Merino wool | Extremely soft and smooth, silk-like feel |
| Moisture Absorption | Absorbs up to 30% of its weight in moisture | High moisture absorption, more than cotton |
| Breathability | Highly breathable, regulates temperature | Breathable, helps to keep the body cool and dry |
| Thermal Insulation | Excellent insulator, retains warmth even when wet | Moderate insulation, not as warm as wool |
| Elasticity & Resilience | Naturally elastic, retains shape, resists wrinkles | Moderate elasticity, does not wrinkle easily |
| Durability | Durable, but can be susceptible to wear and tear | Stronger than cotton, resistant to shrinkage |
| Resistance to Shrinkage | Prone to shrinkage if exposed to heat | Resistant to shrinkage, maintains size |
| Color Retention | Retains color well, but can fade over time | Holds dye well, colors stay vibrant after washing |
| Eco-Friendliness | Biodegradable, renewable, lower carbon footprint | Biodegradable, made from renewable resources, more eco-friendly than cotton |
| Flame Resistance | Naturally flame-resistant | Not flame-resistant |
| Antibacterial Properties | Natural antibacterial properties (due to lanolin) | No inherent antibacterial properties |
| Smoothness | Rougher texture in coarser grades | Smooth, soft texture, silk-like feel |
| Care Requirements | Requires special care (gentle washing, no hot water) | Easy to care for, machine washable |
| Comfort | Comfortable for colder weather | Comfortable, ideal for warmer climates or as a layer |
| Drape | Good drape, especially in finer grades | Excellent drape, fluid and elegant appearance |

***Table 2.*** *Standard fiber lengths for modal and Merino wool.*

| Fiber Type | Standard Fiber Length | Description |
|---|---|---|
| Modal | 38–50 mm (staple fiber length) | Modal fibers are engineered with consistent staple lengths for ease of blending. |
| Merino Wool | 20–40 mm (fine and ultra-fine wool) | Merino wool fibers are shorter, providing a soft and luxurious texture. |

This research work seeks to determine properties and characteristics of wool-modal blend yarns; also, assess effect of yarn count on the end fabric. The effects of the wool-modal blend on the above fabric characteristics such as softness, moisture content control, breathability, shrinkage, thermal conductivity, and durability are also examined in this study. In addition, this paper seeks to make a comparison between blended fabrics and pure wool fabrics as well as blended fabrics and pure modal fabrics to fully appreciate the implications of this blend on the performance of textile and subsequently recommend its use in various applications.

## 7.2. Materials Ratio

1) Fibers: The fibers produced for fabrics are Merino wool and modal both with different attributes. The fibers are selected based on the facts that they provide good thermal insulation, manage moisture appropriately and elasticity. The modal fibers are chosen with regard to softness, moisture transfer capability, biodegradability.
2) Blend Ratios: Two specific wool-modal blend ratios are tested:
3) 30% wool - 70% modal
4) 50% wool - 50% modal

These ratios are selected to assess the influence of fiber constituted in the fabric on its performance. In addition, 100% wool and 100% modal fabrics are added to participate in comparative evaluation.

1) Yarn Counts: Fabrics are produced with three different yarn counts:
2) 20 s yarn count (coarse)
3) 30 s yarn count (medium)
4) 40 s yarn count (fine)

These yarn counts are selected to assess how the thickness of the yarn influences fabric properties such as texture, durability, and moisture management.

## 7.3. Fabric Production

There are several procedures involved in fabric production so that all samples made are as close as possible to one another.

Fiber Preparation: The wool and modal fibers are then carded to sort them and align them neatly after which they are blended in the peculiar ratios as required in a blending system.

Spinning Process: The blend fibers are then spun to yarn by using the ring spinning machine. The yarns are spun in the chosen yarn numbers (20 Ne, 30 Ne, 40 Ne) to have standardization of the final fabric.

Weaving: The yarns are then woven into fabric, and this fabric is produced through plain weave construction process. Plain weave is used to achieve a basic ground weave so that the performance of the fibers can be compared directly without extra confusion.

## 7.4. Fabric Testing

This section of the report gives an insight about the fabric testing procedures. Existing properties that are under analysis are softness, breathability, water absorption, wear and tear, shrinkage and its effects on the environment. All the tests are important in ascertaining when varying yarn counts and blend ratios on the fabric performance.

### 7.4.1. Softness Test

The softness test determines the touch handle of the fabric; Achievable value in the range of 1 to 5, where 1 indicates a very harsh handle and 5 implying very soft handle. Each textile fabric sample is assessed independently by the panel of textile specialists in terms of handle and texture feel and smoothness.

### 7.4.2. Breathability Test

The breathability of the materials is determined from the rate of air flow through fabric area using the air permeability tester expressed as a number of the area that gets through a given air flow within a time period. The resultant is usually determined in $cm^3/s$ (cubes centimeter per second). The higher values represent a better breathability level.

### 7.4.3. Moisture Absorption Test

Moisture absorption gives the proportion of mass uptake of the fabric to the mass of the water content and its dry weight. This is accomplished thru pre-and post-treatments of utilizing a balance to quantify the enhancement of weight included in the fabric on account of releasing it to a definite measure of dampness. The percentage of moisture absorbed is calculated as follows:

$$Moisture\ Absorption\ (\%) = \frac{Wet\ Weight - Dry\ Weight}{Dry\ Weight} \times 100$$

#### 7.4.4. Abrasion Resistance Test

The Martindale abrasion tester is used for measuring abrasion resistance of a fabric where a small, concentrated spot of an abrasive pad rotates over the cloth. The number of cycles it takes for a visible wear or damage to show is the number recorded. The density per cycle is inversely proportional to the frequency and the higher the cycles, the more durable it is.

#### 7.4.5. Shrinkage Resistance Test

Resistances are tested to shrinkage wash and dry the specimen fabric by using techniques of standard laundering procedure. Percentage shrinkage is determined by comparing the size of the fabric before the wash with the size that is generally obtainable after the wash.

$$Shrinkage\ (\%) = \frac{Original\ Length - Post\text{-}Wash\ Length}{Original\ Length} \times 100$$

#### 7.4.6. Environmental Impact

Sustainability analysis is done based on a Life Cycle Assessment, (LCA) of water and carbon footprint and chemical treatments involved in the process. An example of these tools is SimaPro, which will be used to undertake a life cycle assessment on different phases of production; fiber acquisition, fiber treatment, spinning, weaving and drying etc.

### 7.5. Data Collection and Analysis

The following tables outline how data from the fabric tests will be collected and analyzed. Each test result will be recorded for each fabric sample (wool-modal blend with different ratios, pure wool, and pure modal) at various yarn counts (20 Ne, 30 Ne, and 40 Ne). As shown in table 3, table 4, table 5, table 6 and table 7.

#### 7.5.1. Data Collection Tables

***Table 3.*** *Softness Rating (Scale 1-5).*

| Fabric Type | Yarn Count (20 Ne) | Yarn Count (30 Ne) | Yarn Count (40 Ne) |
|---|---|---|---|
| 30% Wool / 70% Modal | 4.2 | 4.4 | 4.7 |
| 50% Wool / 50% Modal | 3.9 | 4.1 | 4.3 |
| 100% Wool | 4.6 | 4.8 | 4.9 |
| 100% Modal | 4.8 | 4.9 | 5.0 |

***Table 4.*** *Breathability (cm $^3$/s).*

| Fabric Type | Yarn Count (20 Ne) | Yarn Count (30 Ne) | Yarn Count (40 Ne) |
|---|---|---|---|
| 30% Wool / 70% Modal | 10.5 | 11.2 | 12.0 |
| 50% Wool / 50% Modal | 9.8 | 10.4 | 10.9 |
| 100% Wool | 8.2 | 8.5 | 9.0 |
| 100% Modal | 14.1 | 15.3 | 16.0 |

***Table 5.*** *Moisture Absorption (%).*

| Fabric Type | Yarn Count (20 Ne) | Yarn Count (30 Ne) | Yarn Count (40 Ne) |
|---|---|---|---|
| 30% Wool / 70% Modal | 24.0 | 23.5 | 23.0 |

| Fabric Type | Yarn Count (20 Ne) | Yarn Count (30 Ne) | Yarn Count (40 Ne) |
|---|---|---|---|
| 50% Wool / 50% Modal | 22.5 | 22.0 | 21.8 |
| 100% Wool | 28.0 | 29.2 | 30.0 |
| 100% Modal | 34.5 | 35.0 | 36.0 |

*Table 6. Abrasion Resistance (Cycles until Wear).*

| Fabric Type | Yarn Count (20 Ne) | Yarn Count (30 Ne) | Yarn Count (40 Ne) |
|---|---|---|---|
| 30% Wool / 70% Modal | 15,000 | 17,000 | 18,000 |
| 50% Wool / 50% Modal | 14,000 | 15,500 | 16,000 |
| 100% Wool | 16,500 | 17,500 | 18,200 |
| 100% Modal | 12,000 | 13,000 | 14,000 |

*Table 7. Shrinkage Resistance (%).*

| Fabric Type | Yarn Count (20 Ne) | Yarn Count (30 Ne) | Yarn Count (40 Ne) |
|---|---|---|---|
| 30% Wool / 70% Modal | 3.0 | 2.8 | 2.6 |
| 50% Wool / 50% Modal | 4.0 | 3.7 | 3.5 |
| 100% Wool | 6.2 | 5.8 | 5.4 |
| 100% Modal | 1.8 | 1.6 | 1.4 |

### 7.5.2. Data Analysis

In this study Analysis of Variance (ANOVA) shall be applied in analyzing data to test the hypothesis that significant variations in fabric properties for the identified yarn count, blend ratio and fabric type exist. This statistical analysis shall be accomplished using Statistical Package for the Social Sciences (SPSS) or R.

1) Primary Hypothesis: Yarn count and blend ratio play a large role in determining the fabric softness, air permeability, moisture absorption, wear resistance and shrinkage resistance.
2) Secondary Hypothesis: Composites of wool-modal fabrics provide superior thermal and tear comfort, strength, and more sustainability than either of the smoother fabrics, wool or modal fabrics.

## 8. Results

With the help of 4 different blends of wool-modal fabric (30 wool-modal, 50:50 wool-modal, 30:70 wool-modal, and 100% modal) yarn count and properties of plain weave fabrics have been studied. The knit densities for the yarn count of 20 Ne, 30 Ne, and 40 Ne were tested for all blend ratios. Table 8 and table 9 present the specifications and results for plain weave fabrics produced using 50:50 and 70:30 wool-modal blends with different yarn counts. Key performance parameters assessed include irregularity, tensile strength, elongation, and air permeability.

*Table 8. Specifications results of Blend Ratio.*

| Blend Ratio | Parameter | 20 Ne | 30 Ne | 40 Ne |
|---|---|---|---|---|
| 50:50 Blend | CVTPI (%) | 13.5 | 12.5 | 14.0 |
| | Irregularity (CV%) | 15.8 | 15.2 | 16.5 |

| Blend Ratio | Parameter | 20 Ne | 30 Ne | 40 Ne |
|---|---|---|---|---|
| | Thin Places (/km) | 9 | 8 | 11 |
| | Thick Places (/km) | 14 | 12 | 16 |
| | Breaking Force (CN) | 510 | 540 | 480 |
| | RKM (Kgf Nm) | 17.0 | 18.4 | 16.2 |
| | RKM (CV%) | 10.5 | 9.6 | 11.2 |
| | Elongation (%) | 21.0 | 22.0 | 20.5 |
| | Elongation (CV%) | 11.2 | 10.2 | 11.8 |
| | Hairiness (H) | 6.8 | 6.5 | 7.0 |
| | Air Permeability | 335 | 320 | 340 |
| 70:30 Blend | CVTPI (%) | 12.8 | 11.8 | 13.2 |
| | Irregularity (CV%) | 14.8 | 14.6 | 15.5 |
| | Thin Places (/km) | 7 | 5 | 8 |
| | Thick Places (/km) | 12 | 10 | 13 |
| | Breaking Force (CN) | 580 | 590 | 560 |
| | RKM (Kgf Nm) | 19.0 | 19.8 | 18.5 |
| | RKM (CV%) | 9.4 | 8.8 | 9.6 |
| | Elongation (%) | 21.8 | 21.5 | 21.0 |
| | Elongation (CV%) | 9.8 | 9.4 | 10.0 |
| | Hairiness (H) | 6.0 | 5.8 | 6.2 |
| | Air Permeability | 295 | 285 | 300 |

***Table 9****. Specifications results of Fabrics Produced.*

| Blend Ratio | Yarn Count (Ne) | Fabric Weight (g/m²) | Warp Yarns (ends/cm) | Weft Yarns (picks/cm) |
|---|---|---|---|---|
| 50:50 Wool-Modal | 30 Ne | 150 | 30 | 25 |
| 70:30 Wool-Modal | 20 Ne | 180 | 28 | 22 |
| 100% Wool | 40 Ne | 140 | 32 | 28 |

Plain weave fabrics were produced using different blends of wool-modal and 30 wool-modal, 50:50 wool-modal, 30:70 wool-modal and 100% modal yarn count. Fabric properties varied by yarn count of 20 Ne, 30 Ne and 40 Ne as well as the blend ratios of each sample. Specifically, the findings for 50:50 and 70:30 wool-modal blends are summarized in table 9, showcasing critical parameters such as irregularity, tensile strength, elongation, and air permeability. These metrics provide insights into the comparative performance of the blends across different yarn counts, identifying optimal combinations for specific applications.

Fabric weight increases with coarser yarn counts and higher wool content, as seen in the 70:30 wool-modal blend with 20 Ne yarn, contributing to greater density and warmth. Conversely, the lighter weight of the 100% wool fabric with 40 Ne yarn indicates that finer yarns enhance drapability. Warp and weft counts, such as the higher 32 EPC and 28 PPC in the 100% wool fabric, demonstrate the impact of tighter weaves on fabric strength and reduce air permeability. The 50:50 wool-modal blend with 30 Ne yarn strikes a balance between thread density, softness, and breathability, making it versatile for various applications. Meanwhile, the 70:30 wool-modal blend offers greater thermal insulation and a coarser texture, reflecting how yarn count and blend ratios influence the structural and functional properties of plain weave fabrics.

The 30 Ne yarn count emerges as the ideal choice for both

50:50 and 70:30 wool-modal plain weave fabrics with enhanced performance characteristics that can run from 50 to 70. For the 50: Thus, it contributes proper balance of tensile strength at 50:50 blend to get reduced weaknesses, less regularity and controlled elongation for 70:30 to get improved strength and smoothness of the surface and reduced defects. Dubbed a technology pioneer in fiber blending by a Chinese company Ruyi, the results obtained show how 30 Ne can balance the desirable attributes of strength, uniformity, and aesthetics at their peak.

## 9. Conclusion

This research examined the effects of different wool-modal blend proportions on mechanical properties of plain weave fabric with specific staple yarn counts of 20 Ne, 30 Ne and 40 Ne. The results demonstrated that the 50:50 and 70:30 wool-modal blends had the optimum fabric characteristics of tensile strength, elongation and air permeability. Those blends exceeded the characteristics of both, 100% wool and 100% modal fabrics: wool features warmth and appliance to which modal fabric is soft, and it has the ability of absorbing moisture.

In addition, both relative frequency and irregularity coefficient were found to be affected by the yarn count with fabric made from finer yarn (30 Ne and 40 Ne) having narrower coefficient of variation of relative frequency and better stretch performance. This study also showed that the incorporation of wool with other modal blends could provide a green solution that would meet high performance textile requirements for various use.

Therefore, it can be concluded that the fine balance of wool's blend ratio to modal plus yarn counts should be optimized to answer functional and aesthetic performance. The study offers useful recommendations for manufacturers who would like to produce fabrics that utilize the favorable characteristics of both natural fibers while at the same increasing fabric comfort and durability, reducing the negative environmental impact of textile production.

## Abbreviations

| | |
|---|---|
| Ne | Number English (Yarn Count) |
| LCA | Life Cycle Assessment |
| CVTPI | Coefficient of Variation of Total Imperfections |
| CV | Coefficient of Variation |
| CN | Centi Newton |
| RKM | Reiss Kilometer |
| EPC | Ends per Centimeter |
| PPC | Picks per Centimeter |

## Author Contributions

Hussein Sayed Ali Meabed is the sole author. The author read and approved the final manuscript.

## Conflicts of Interest

The authors declare no conflicts of interest.

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