QUALITY ASSESSMENT OF UAS SHEEP BREED WOOL BLENDS

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QUALITY ASSESSMENT OF UAS SHEEP BREED WOOL BLENDS

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IN

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BY

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CERTIFICATE

This is to certify that the thesis entitled "QUALITY ASSESSMENT OF UAS SHEEP BREED WOOL BLENDS" submitted by Miss VIDYA V. SANGANNAVAR, for the degree of MASTER OF HOME SCIENCE in TEXTILE AND APPAREL DESIGNING to the University of Agricultural Sciences, Dharwad is a record of research work carried out by her during the period of her study in this University, under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

DHARWAD
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With regardful memories……..

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Abbreviations		Description
UAS	:	University of Agricultural Sciences
r-PET	:	recycled- polyethylene terephthalate
Nm	:	Metric system of yarn count
tpi	:	twist per inch
kgf	:	kilogram force
U %	:	Unevenness percentage
Ne	:	Numerical expression
GSM	:	Gram per square meter
tog	:	Heat transfer to 10 wm^{-2} (watt per meter square) per degree temperature difference

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1. INTRODUCTION

Quality is examined as a quantifiable attribute based on the product's performance such as durability or reliability. It is assessed in the field of textiles and apparels depends on type of raw material, method of spinning, yarn and fabric design, wet processing and finishes applied. In order to produce a quality product, textile manufacturers need to understand the term quality which will allow them to measure how far their products meet the requirements and satisfy the consumers demand. Presently, great varieties of textiles are manufactured by using various natural fibres, synthetics and blends of these fibres for various end uses.

Natural fibres have greater potential and impact on textile performance in the areas of comfort, maintenance and durability. Among the different kinds of natural fibres, wool is one of the versatile fibre due to its unique inherent properties and plays a vital role in textiles industry.

Wool is highly valued for a wide range of properties. It can absorb upto 30 per cent moisture to its own weight without feeling wet. The natural crimp and resilience of wool fibres helps to maintain high loft and thermal insulation of fabrics. Hence, it is an ideal material for cold and humid climate conditions. Although not a very strong fibre, wool is highly extensible, flexible and resilient. These properties makes the wool fabrics better handle, drape and fashion style (Johnson and Russell, 2008).

According to Ministry of textile annual report (2013-2014), India is the seventh largest producer of wool and contributes 1.8 per cent to total world production and it is the 3rd largest sheep population country in the world having 7.15 crores sheep producing 48.77 million kg of raw wool per year. Out of this, about 85 per cent is carpet grade wool, 5 per cent apparel grade and remaining 10 per cent coarser grade wool for making rough kamblis. Average annual yield per sheep in India is 0.9 kg, against the world average of 2.4 kg per sheep per year. There are around 958 woolen units in the country, majority of which are in the small scale sector. The industry provides employment in the organized wool sector to about 12 lakh people, with an additional 12 lakh persons associated in the sheep rearing and farming sector. Further, there are 3.2 lakh weavers in the carpet sector and about 27 lakh people engaged in wool products. Due to ever growing demand of wool products there has been a continuous expansion and modernization of wool based industry.

The wool industry of India presently facing various problems including short supply of quality wool fibres. Therefore, the efforts are made to improve the wool quality through cross breeding as there is a large gap between the availability and estimated demand of wool. But this proved to be very expensive for sheep farmers, as cross breeding animals are relatively more susceptible to diseases. Wool is grown in all parts of the world. In Australia and New Zealand, it is a major product and sheep are raised primarily for wool (Sharma and Goel, 2003).

In 1940, some exotic breeds Cheviot, Border, Leicester, Weinsleydale from Britain and Merino from Australia were introduced to Jammu and Kashmir and their performance was encouraging. Since 1951, quite a few exotic sheep have been introduced to India, the main breeds being Rambouillet, Polworth, Corriedale, Border, Leicester, Spanish Merino, German land Merino, Somali, Southdown, Romney Marsh and Russian Merino. The performance of Rambouillet was comparatively better among these breeds. The cross breeding programmes have been taking place all most in all the states under the national state breeding policies (Bidikar, 1998).

The wool production potential of native breeds of sheep is not satisfied to meet ever increasing demand of wool of the state as well as India. Several exotic breeds of sheep have been introduced in the region for cross breeding of the local sheep for improving production and quality of wool.

Improving the quality and quantity of Indian sheep breeds, some of the exotic sheep started in the beginning of nineteenth century. The breeds mainly imported during this period were Southdown and Cape Merinos. During twentieth century Merino and Romney Marsh were imported to the states of Uttar Pradesh, Punjab and Karnataka. In 1938, some Merinos introduced in the sheep breeding research station, at Pune and cross breeding of Deccani sheep was under taken (Bidikar, 1998).

Development of UAS sheep breed wool

The indigenous breeds of Karnataka *viz.,* Deccani and Bannur are known for quality mutton production but are lacking in production of superior quality wool. Southdown breed originated in England produces white, medium wool. This breed is helpful in crossing programmes for improving the wool quality of the native breeds. Hence an effort was made in 1950, to crossbreed the Southdown and Bannur at Regional Research Station (RRS), University of Agricultural Sciences (UAS), Dharwad. The outcome generation was then crossbreed with Deccani. The resultant product named as University of Agricultural Sciences (UAS) sheep breed, a product of crossing Southdown, Bannur and Deccani breeds (Fig. 1).

This breed has combination of 50 per cent Deccani, 25 per cent Bannur and 25 per cent Southdown. This breed has advantages over the native breed with respect to faster growth rate, softer and crimpy, average fleece weight is about 355.18 g/ animal.

The UAS sheep breed wool has very low tensile strength and elongation compared to Deccani and Bannur. The fibres as alone not suitable for production of textiles *i.e.*, kamblis. Kambli weaving is one of the oldest traditional cottage industry and many rural folks depends on kambli weaving for their livelihood. Among the caste and creed majority of the people belong to kuruba community who are involved in rearing of sheeps and weaving kamblis since time immemorial. Among the districts the Chitradurga ranks first followed by Tumkur and Haveri district in the blanket weaving. Challakere taluk of Chitradurga district is recognized as a famous kambli trading centre. The kamblis are popular in Malanad taluks of Karnataka, Tamilnadu, Andhra Pradesh and Maharastra. All the weavers are working under co-operativ fold on pit looms and there are 18 primary woolen weavers co-operative societies working for about 2650 woolen weavers all over the taluks.

In the local area the UAS sheep breed is mainly reared for the purpose of meat, from each sheep 300 - 400 g of fleece is generated by every clipping per year. Due to shorter, coarser and lower strength of UAS sheep fleece, the local weavers are not ready to using fleece for the production of kamblis. The UAS sheep fleece can be improved through blending with other stronger natural and manmade fibres.

Blending wool with other natural and synthetic fibres

All textile fibres have their own inherent characteristics in terms of market value, look, feel, physical as well as chemical properties etc, due to which products made of any one among these is not capable of meeting all the end user requirements. This has prompted to blend fibres to reduce

cost of product and enhance the physical properties like mechanical, functional and aesthetics properties, finally paving way for overall improvement of textiles. Fibres can be blended in two major ways, e.g. intimate and physical blending. Intimate blending is of conventional type in which staple fibres of various textiles are mixed thoroughly and spun together to get the blended yarn. In contrast, physical blending is carried out during weaving to produce union or blended fabrics.

Blending refers to the sequence of processes required to convert two or more kinds of staple fibres into a single yarn composed of a mixture of the component fibres. Today advancement of blending technology, variegated yarns and fabrics are possible to design with different fibres combinations which are suitable for different end uses with specific function. The pure wool is not always the most preferred among consumers; therefore manufacturers are going for blending.

Blending is a way of value addition in the utilization of coarse varieties of wool available in the country. There is a need to develop diversified products and innovative blending processes that will make possible usage of coarser varieties like blankets, shawls, furnishing and to enrich the properties such as strength, appearance, comfort etc. (Sharma and Goel, 2003).

Today, the consumers are more concerned with the overall performance of the fabric and they don't demand that the fabric should be pure. In the export market too, the focus is now more on uniqueness of fabric in terms of look, texture etc. therefore new blend experimentation is encouraged. The world is now looking for eco-friendly natural products, which are exclusive and fulfill the needs of the common people. It is found that products made by using blends of natural fibre have been found to have higher acceptability level (Goel *et al.,* 2011).

Wool is blended with other fibres to utilize the respective advantages of the other fibres. These advantages may be either unattainable, undesirable side effects or be too costly if only one type of fibre is used. The advantages may relate to comfort, appearance or style, durability, ease care and specialized functionalities such as heat and flame resistance, conductivity, chemical and biological behaviours. Commercial point of view, blends are formed to reduce the total cost of production, improve the performance properties and creates market demand (Johnson and Russell, 2008).

Cotton/ wool blends combine the comfort properties of cotton and warmth and durability of wool. These fabrics are growing in popularity due to increased consumer demand for styling, comfort and eco-friendly natural fibres. Moreover, in Indian climatic conditions, during pre and post winter season use of cotswool is very popular for apparel purpose (Sharma *et al.,* 2015).

Wool/ polyester blends have better evenness, moisture absorption and warmth, higher breaking and abrasion strength, less pilling and static electrification, easier spinning and care properties. The polyester/ wool blended yarns are recommended for making sportswear fabric where durability and stretch ability both are required for providing comfort during sport activities. (Tripathi *et al*., 2013)

Jute is a natural fibre popularly known as the golden fibre. It is one of the cheapest and the strongest of all natural fibres and is considered as fibre of the future. Traditionally jute fibre has been used to manufacture the packaging materials like hessian, sacking, ropes, twines and home textiles as carpet, carpet backing cloth etc. In order to overcome the declining market of these conventional

products of jute, new technologies and diversification have been evolved for bulk use of jute, as a raw material in the production of high value added and price competitive intermediaries or final products. Recently, due to the improvement of people's living standards and need for environmental protection, the demand of natural biodegradable and eco-friendly fibres is rising worldwide day by day. The increased demand of natural fibre is due to their low cost, low density, biodegradability, renewability and abundance. The jute is effectively blended with other natural synthetic fibre to enhance the end product property.

The present work discovers a new concept & technique for blending the weaker UAS sheep breed wool with other stronger fibres like acrylic, recycled polyethylene terephthalate (r-PET) and jute to manufacture novelty yarn using existing wool spinning processing machineries. Effective blending provides a better scope for utilizing the advantage of the intrinsic properties of the component fibres and performs mainly to endow the required characteristics to the end products, compensates for variation in the characteristics of the raw materials and to hold down raw material cost. Physical properties of yarn are very important for post-spinning operations as well as for determining final fabric characteristics. Therefore an attempt is made to improve and enhance the underutilized UAS sheep breed wool with following objectives.

1. To explore the spinning possibilities by blending UAS sheep breed wool with man-made and natural fibre
2. To find out the physical properties of blended yarns
3. To develop plain woven blended fabrics
4. To assess the mechanical and functional properties of blended fabrics
5. To enumerate the cost of production of blended fabrics

2. REVIEW OF LITERATURE

This chapter includes the relevant research articles available pertaining to the present investigation on “Quality assessment of UAS sheep breed wool blends”. The review of literature relevance to the present study is arranged in this chapter under the following sub headings,

2.1 Blending and spinning methods

2.2 Properties of wool blended yarns

2.3 Properties of wool blended fabrics

2.1 Blending and Spinning methods

Blending is a mixture of two or more kinds of staple fibres to form a single yarn. Fibre blending has assumed increasing importance with the rapid development of man-made fibres. Homogeneity is an important aspect to be considered in connection with blending. Blending can be done at various stages as mentioned below:

- In the initial opening stage of the blow room operation, the fibres are spread one on top of the other and fed into the blending feeder
- The blending can be done in the carding stage
- Similarly the blending can be done at drawing or roving stage

Spinning is defined as the process of insertion of twist to the yarn. Spinning can be divided into the following three basic operations:

- Attenuation of the roving, sliver or slubbing to the required linear density
- Imparting cohesion to the fibrous strand, usually by twist insertion
- Winding the yarn onto an appropriate package

Papnai and Goel (2005) carried a research on “Blending for yarn amelioration”. The Rambouillet wool and Mulberry silk waste were opened thoroughly in willow machine and blended in fibre blender with different ratios *viz.,* 65/35, 50/50 and 35/65 respectively. The blended fibres were disentangled, straightened and arranged in a parallel form by feeding one lap of the blended fibres into a small carding machine to condense the sliver suitable for spinning. The spinning was carried out on Bageshwari charaka for preparation of single ply yarns. It was found that spinning on Bageshwari charaka was found to be suitable for production of single, ply blended yarns with different counts and with better yarn properties.

Kariyappa *et al*. (2006) reported on “Studies on blending of Eri silk with wool fibres in spinning and its characterization” carried out at Central Silk Board, Bangalore. The wool and silk fibres were blended in varied proportions *viz.,* 70/30, 60/40, 50/50 and 30/70 respectively. Depending on blend ratio the required quantity of wool and Eri silk slivers were fed to gill box, followed by combing, gill box, 2nd combing and 4 times gill box treatment. The results concluded that, gill box (draw frame) stage of blending was found to be better choice for Eri silk and wool blend for spinning than blending in opener stage.

Ghasemi *et al.* (2008) studied on “Comparing the physical properties of produced siro-spun and new hybrid solo-siro spun blend wool/ polyester worsted yarns”. The wool/ polyester worsted blend (45/55) yarns were produced on siro-spun and new hybrid solo-siro spinning systems. The physical properties of the produced yarns were investigated and compared. The results revealed that, utilizing a solo-spun roller in the worsted siro-spun spinning system significantly improves the hairiness properties of the blended wool/ polyester yarn. The evenness, count and twist of solo-siro spun yarns changed slightly in comparison with siro-spun yarns. The blended yarns spun on solo-siro spinning system exhibited more evenness, higher yarn count and twist than the siro-spun yarn.

The perusal of the study on “Blending and processing of wool with specialty hair fibres to empower rural women” carried out by Sharma and Goel (2012). The Rambouillet, Imbu and Angora hair fibres were blended in three ratios *viz.,* 35/65, 50/50 and 65/35 respectively. The pure and blended yarns were prepared on two different spinning systems *viz.,* Bageshwari and Pant charaka. The fabrics were developed using knitting technique, properties were evaluated and compared among the two systems. The study showed that, the fabrics developed from yarns spun on Bageshwari charaka exhibited better strength, high abrasion resistance, bending length and less thickness compared to the fabrics developed from blended yarns spun on Pant charaka.

Sharma and Pant (2012) analyzed on “Impact of blending wool fibres with kid camel hair on strength of yarn”. Camel hair was blended with three varieties of wool fibres *viz.,* Merino, Chokla and New Zealand in varied blend proportion *viz.,* 25/75, 50/50 and 75/25 respectively. Camel hair and wool fibres were thoroughly opened and blended manually with the help of cordes and sandwich blending technique was used for the blending of fibres. Woolen carding system was adopted for carding of blended fibres and spun on Ghantaria charaka. It was found that, Ghantaria charaka can be effectively used for spinning the wool blended yarn with minimum yarn imperfection.

Tripathi *et al.* (2013) conducted a study on “Evaluation of Quality parameters of ring spun polyester and wool blended yarns for sportswear fabric”. The polyester and wool fibres were blended in different proportions *viz.,* 70/30, 60/40, 40/60 and 15/85 respectively. The pure and blended fibres were processed in woolen spinning system and yarns were developed on ring spinning system. The results concluded that blended yarns spun on woolen and ring spinning system possessed higher strength and better elongation percentage further recommended for production of sportswear fabrics.

A study on “Value addition of Mulberry silk waste/ wool blends to develop handloom fabrics” was carried out by Verma *et.al* (2013). Gillbox (drawframe) blending method was adopted for blending of mulberry silk waste and wool fibres in the ratios of 65/35 and 50/50. The study revealed that, the mulberry silk waste and wool fibres can be blended at the gillbox stage to prepare yarns of 30 and 40sNm.

Goel (2015) analyzed on “Muga silk and Rambouillet wool: A unique combination for yarn”. The Muga silk and Rambouillet wool were blended in varied proportions (30/70, 50/50 and 70/30) and spun on hand and machine spinning. The blended yarns spun on different spinning methods were further assessed for physical properties. The study revealed that, the blended yarns spun on machine spinning showed finer count, better strength and elongation percentage, evenness properties than the hand spun blended yarns due to constant speed of machine.

2.2 Properties of wool blended yarns

Yarn is defined as a linear assemblage of fibres or filaments formed into a continuous strand. Yarn occupies the intermediate position in the manufacture of fabric from the raw material. Yarn testing is very important, both for estimating the quality of raw material and for controlling the quality of fabric produced. The properties of yarns involves the yarn count, twist per inch, yarn evenness, tenacity and elongation percentage.

Biradar (2000) reported on "Blending of polyester with wool on long staple spinning for suitings". Blends containing 40 to 60 per cent of polyester with wool were spun on worsted spinning systems and further yarns were used for production of suiting's. The suiting's were found to be resilient because of high degree of resiliency of polyester and wool fibre. Blended suiting's provides warmth, water repellent, wrinkle recovery and possessed natural flame retardance and does not encourage the generation of static charges.

Kothari and Bari (2002) analyzed on "Properties of polyester/ wool parent and air-jet textured yarns and their fabrics". The polyester/ wool (70/30) blended yarn was subjected to air-jet texturing and the physical properties were analyzed and compared with parent blended yarn. The results revealed that air-jet texturing improved the bulk and linear density of polyester/ wool blended spun yarns. Whereas, the tensile strength decreases significantly and the unevenness of the yarn increases in air-jet textured yarn.

Mishra and Goel (2004) conducted a study on "A value added blend of Angora rabbit hair and Merino wool fibre" carried out at Kumaon region of Uttaranchal. The angora rabbit hair and merino wool fibres were blended in 100 per cent, 65/35, 50/50 and 35/65. The Bageshwari charaka was used for spinning. The study depicted that, the blended yarn of Angora rabbit hair/ Merino wool (35/65) yarn showed more evenness, better strength and elongation percentage with higher twist per inch and found to be low cost than the blended yarn of 50/50.

Wang *et al.* (2005) reported on "Wool and alpaca fibre blends". In this study, three types of blends at two blend ratios were developed *viz.,* fine alpaca/ superfine low-crimp wool (30/70), fine alpaca/ superfine high-crimp wool (30/70) and strong alpaca/ super wash wool (50/50) respectively. The developed blended yarns were subjected to yarn count, evenness, tenacity and elongation properties. The study concluded that, the blending of alpaca fibre with wool improves the cohesion properties of the blend sliver with high-crimp. There was no significant difference in yarn count and yarn evenness between alpaca/ low-crimp wool and alpaca/ high-crimp wool blend yarns. The alpaca/ low-crimp wool blend yarn had higher tenacity and elongation percentage than alpaca/ high-crimp wool blend yarn.

Kariyappa *et al*. (2006) analyzed on "Studies on blending of Eri silk with wool fibres in spinning and its characterization" carried out at Central Silk Board, Bangalore. The wool and silk fibres were blended in varied proportion (70/30, 60/40, 50/50 and 30/70) spun on hand spinning machine and the properties were assessed. It was found that, blended yarns possessed higher strength and elongation percentage, whiteness index and better hand value than the pure yarn.

Goel *et al*. (2010) carried a study on “Cotton and Tibetan wool yarns - An eco-friendly blend for designer durries”. In this study, the raw materials were procured from Pantanagar (Tibetian wool) and Rudrapur (cotton). The cotton and wool were blended in different ratios *viz.,* 65/35, 35/65 and 50/50 respectively. The results showed that, maximum yarn count & tenacity was observed in cotton/ wool (65/35) blend. The blended yarn of 35/65 showed more even, better strength and elongation percentage and higher tpi than the blended yarn of 50/50.

Qian *et al.* (2010) investigated on “Measuring the blend ratio of wool/ cashmere yarns based on image processing technology”. The three kinds of wool/ cashmere blended yarns with different proportions (90/10, 80/20 and 70/30) were subjected to image processing technique and support vector machine to calculate the blend ratio of wool/ cashmere yarns. The study revealed that, the experimental results match the factual situation very well which suggests that testing the ratio of wool/ cashmere blend yarn by image processing technique was practicable with high accuracy.

Sharma and Pant (2012) analyzed on “Impact of blending wool fibres with kid camel hair on strength of yarn”. The camel hair was blended with the three varieties of wool *viz.,* Merino, Chokla and New Zealand in varied blend proportions (25/75, 50/50 and 75/25). The blended yarns were assessed for physical properties. The One-way analysis of ANOVA was conducted to determine the influence of different blend ratio on strength of yarn. Tenacity values were significantly different for camel hair/ merino ($F=30.47$, $P<0.01$), camel hair/ Chokla ($F=13.08$, $P<0.01$) and camel hair/ New Zealand ($F=2.76$, $P<0.05$) indicated that blending of camel hair with other fibres significantly affected strength of yarns. It was found that among the blends, camel/ Merino (25/75) was superior to other blends.

Pant and Sharma (2012) carried out a research on “Performance of camel kid hair: acrylic blended yarn and knitted fabric”. Camel hair was blended with acrylic in different proportions 75/25 and 50/50 spun on khadi hand spinning system. Blending of acrylic with kid camel hair improved fineness and strength of yarn. The blend ratio 75/25 exhibited higher fineness and tenacity than the 50/50 blended yarn.

The perusal of the study on “Blending and processing of wool with specialty hair fibres to empower rural women” carried out by Sharma and Goel (2012). The Rambouillet, Imbu and Angora hair fibres were blended in three ratios (100 per cent, 35/65, 50/50 and 65/35). The results revealed that blending of Angora hair fibre and wool fibre can produce luxurious products, which are cost effective and beautiful. Thus by disseminating the knowledge of such techniques to the rural women, their financial status can be improved which will help in the upliftment of women, society and state.

Sharma and Pant (2013) investigated on “Studies on camel hair-Merino wool blended knitted fabrics”. Kid camel hairs of Bikaneri breed and Merino wool were selected for the study. The camel hair was blended with merino wool in varied proportions *viz.,* 25/75, 75/25 and 50/50 respectively. The blended yarns were assessed for physical properties and the study depicted that, among the blended yarns the camel kid/ merino wool (25/75) blended yarn possessed better yarn properties *viz.,* yarn count (12.91), twist per inch (13.33), tenacity (2.017) and elongation percentage (6.396) than the other blends due to higher percentage of merino wool.

Sharma and Pant (2013) conducted a study on “Properties of camel kid hair: Chokla wool blended yarns and fabrics”. Camel hair was blended with Chokla wool in three proportions (25:75, 50:50 and 75:25) spun on Khadi hand spinning system. The properties of blended yarns were evaluated by using standard test methods. The results revealed that pure Chokla wool yarn was finer and more uniform than pure camel hair yarn. Fineness of camel hair yarns improved on blending Chokla wool with camel hair. The pure camel hair yarn showed minimum tenacity value with higher CV per cent as compared to other pure as well as blended yarns. It was clear from the study that blending of camel hair with Chokla wool fibres resulted in decrease in strength of yarn. It was concluded that, blending of Chokla wool with camel hair significantly adds value to the camel hair yarn.

Tripathi *et al.* (2013) conducted a study on “Evaluation of quality parameters of ring spun polyester and wool blended yarns for sportswear fabric”. The polyester and wool fibres were blended in 100 per cent, 70/30, 60/40, 40/60 and 15/85. Further, six types of blended yarns were developed on ring spinning system. The study concluded that, as the polyester proportion increased in the blended yarn the strength of the yarn was increased significantly. The polyester has high molecular orientation and crystallinity lacks in elongation can further improved by adding wool in the blended yarns. The blended yarns provide a better resiliency and comfort suitable for sportswears.

A study on “Optimization and prediction of the pilling performance of weft knitted fabrics produced from wool/ acrylic blended yarns” was conducted by Rejali *et al*. (2014). Effects of fibre, yarn and fabric parameters on the pilling performance of weft knitted fabrics produced from wool/ acrylic blended yarns have been studied using Taguchi’s experimental design the pilling performance were blend ratio, yarn twist multiple and count, number of feeding yarns, fabric structure and knit density. According to the signal-to-noise ratio analysis, it was observed that the used materials type and the number of feeding yarns had the largest and smallest affect on the pilling performance respectively. Knit density was the second factor affected the pilling performance of the knitted structures and was followed by factors knit structure, yarn twist and yarn count. The factors considered to assess the maximum and minimum errors of prediction were found to be 4.18 per cent and 0.21 per cent respectively. The average of predicted error of the number of pills for weft knitted fabrics was 1.92 per cent and results showed that good capability and predictive power of artificial neutral network algorithm to predict the pilling performance of weft knitted fabric.

The Wool Research Association, Thane carried out a research on “Effect of blend ratio on yarn evenness and imperfections characteristics of wool/ polyester ring-spun yarn”. The blended yarn of wool and polyester of 40s and 60s count in varied blend proportion *viz.,* 75/25, 65/35, 55/45 and 40/60 were spun on conventional worsted system. The results revealed that, blended yarns possessed less total yarn imperfections and more evenness with increased polyester content (Samanta, 2014).

2.3 Properties of wool blended fabrics

The assessment of the fabric properties is very important to know the performance and durability of the fabric. The geometric properties of the fabric lays a basic foundation to the fabric, on which the performance and durability properties of the fabric depends. The geometric properties of the fabric involves threads per unit area, fabric thickness and GSM. The functional properties of the fabric involves dimensional stability, drapability, tenacity and elongation, abrasion and pilling resistance. The functional properties of the fabrics mainly depends on the geometric properties.

Shekar *et al.* (2001) studied on “Influence of wool-synthetic fibre blends on thermal insulation”. The wool was blended with polypropylene and acrylic in the proportions 50/50, 70/30 and jute in the proportion of 85/15 were further used for the production of five different types of blankets. Among the wool/ synthetic blankets, the wool/ acrylic (70/30) blanket has showed higher insulation and thermal resistance in both dry contact and dry spacer method. This may be attributed to the higher percentage of wool in the blended yarn and thickness of the blanket. Similarly the wool was blended with polypropylene and acrylic in the proportions 50/50 and pure polypropylene were further used for the production of four different types of knitted intimates by utilizing the plain, rib and terry knits. Among the wool/ synthetic intimates, the wool/ acrylic (rib knit) intimate has showed higher insulation and thermal resistance in both dry contact and dry spacer method. The study concluded that, the high insulation values were observed in knitted fabrics as compared to woven fabrics due to the higher proportion of air to fibre volume.

Kothari and Bari (2002) analyzed on “Properties of polyester/ wool parent and air-jet textured yarns and their fabrics”. The polyester/ wool blended yarn was air-jet texturized in air-jet texturizing machine. The polyester/ wool (70/30) and air-jet textured polyester/ wool (70/30) were used for the production of woven and knitted fabrics. The study revealed that, woven and knitted fabric with air-jet textured yarns possessed lower air permeability, higher thermal resistance, higher abrasion resistance and inferior strength properties compared to the parent yarn fabrics with parent yarns.

Sharma and Goel (2003) reported on “Comparative study of fabrics formed by blending Rambouillet and Imbu wool fibres”. In the study, fabrics were woven on handloom with the blended yarns of Rambouillet and Imbu wool fibres in varied proportions *viz.,* 75/25, 50/50 and 25/75 respectively. The study concluded that, the blending of Imbu wool with Rambouillet brings about the favorable changes in the performance of resultant fabric. The increase of Imbu wool fibre in the blend, the weight and stiffness of fabric also increased, however the blended fabric has comparatively higher strength than the pure Rambouillet wool fabric.

Long and Wei (2004) carried out a research on “Pilling of polyester/ wool blends”. The different types of fabrics were designed using wool, polyester and modified polyester in varied proportions (wool/ polyester- 45/55, wool/ polyester- 60/40, wool/ modified polyester - 45/55 and wool/ modified polyester – 60/40). The samples were subjected to pilling test with circular focus pilling tester. It was observed that number of pills in all the samples increased with increase in brush time. Among the samples, wool/ modified polyester fabric showed greater pilling resistance than the others due to low strength and modulus of the modified polyester.

Singh *et al.* (2004) reported on “Comparative study of woollen blanket and jute-wool blanket”. The pure woolen blanket was prepared from 50/50 Rambouillet and Chokla wool in warp and 80/20 Rambouillet and Chokla wool in weft. The union blanket was woven with cent per cent jute as warp and cent per cent wool as weft. All the wool blankets were processed by washing, milling, steaming, brushing and raising using standard machines. The results inferred that, the fabric density, thread density and warp way strength increased remarkably due to milling and raising in case of woolen blanket whereas these changes were not remarkable in case of jute-wool blanket. In general washing and milling process improves the warp strength and low weft strength loss in all the blankets.

Wang *et al.* (2005) reported on “Wool and alpaca fibre blends”. In this study, three types of blends at two blend ratios were developed *viz.,* fine alpaca/ superfine low-crimp wool (30/70), fine alpaca/ superfine high-crimp wool (30/70) and strong alpaca/ super wash wool (50/50). The developed blended yarns were further utilized for the production of knitted fabrics. The study concluded that, the alpaca/ wool blended fabrics exhibited similar pilling performance and the dimensional changes are basically stable after the stress relaxation of blend fabrics. Also the alpaca/ low-crimp wool blended fabric was softer than that the alpaca/ high-crimp wool blended fabric.

Patni *et al.* (2006) carried out a study on “Studies on animal fibre blended hand made felts: Part I- physical and mechanical properties”. The wool fibre was blended with camel hair and Angora rabbit wool in different proportions, which were further used for production of felts of different thickness and densities as per Indian standards. The study revealed that, the thickness of wool and wool blended felts was higher than that of camel hair blended felts due to the coarseness of wool. The density of camel blended felts was higher than that of wool blended felts due to the hollowness of wool fibre. The tensile strength and splitting resistance were influenced by surface characteristics of fibres and thickness of felt.

Shakyawar *et al.* (2007) analyzed on “Studies on animal fibre blended handmade felts: Part II – frictional, compressional and thermal properties”. The handmade felts were prepared from wool, camel, rabbit hair and their blends. It was observed that, felts developed from rabbit hair and its blends were found to be smoother, warmer and softer than the felts produced from camel hair and sheep wool. The coefficient of friction and resiliency was highest in the felts made from sheep wool than those of felts produced from camel hair. Statistically, the compressibility was influenced by combined effect of medullation and areal density, where as the resiliency was significantly related to areal density with negative relation. The thermal conductivity was significantly related to fibre diameter with positive relation.

Kariyappa *et al.* (2007) carried out a research on “Studies on influence of Eri/ wool fibre blending on abrasion resistance of Eri/ wool blended fabric”. The pure Eri silk, pure wool and Eri silk/ wool (70/30, 60/40, 50/50 and 30/70) blended fabrics were developed and subjected to physical properties. The study inferred that, the fabric thickness, blend proportions, moisture regain and GSM influences the fabric properties with positive correlation. As the Eri silk content increases in blended fabric, the durability, stiffer, softer, smoothness, comfort and dimensional stability were improved.

Li *et al.* (2008) reported on “The dimensional and mechanical properties of wool/ polyester fabrics made from vortex and ring-spun yarns”. In this study, the fabric samples woven from a combination of steamed and un-steamed Murata vortex spun (MVS) yarn and worsted ring-spun yarn were subjected to dimensional and mechanical properties. Greater hygral expansion and relaxation shrinkage were found in fabrics made from un-steamed MVS yarns than the loomstate fabrics made from steamed MVS and ring spun yarns. The reduction of relaxation shrinkage levels of fabrics developed from un-steamed MVS yarn by pressure steaming was found to be more effective and after pressure steaming, all fabrics showed similar levels of relaxation shrinkage and hygral expansion.

Raja and Thilagavathi (2009) studied on “Development of union fabrics using short fine wool yarn and cotton yarn”. Two types of wool-cotton union fabrics were produced using two different counts of wool yarns spun from short fine wool as weft and colored cotton yarns as warp. The performances of finished union fabrics were compared with the pure wool control fabric to find out the suitability of blankets for tropical winter season. The union fabrics exhibited 40 to 50 per cent reduced felting shrinkage compared to 100 per cent wool control fabric. Based on the thermal and air resistance values of the wool-cotton union fabrics can be used as blankets for moderate winter seasons in tropical countries.

Al-Shibi *et al.* (2012) carried a study on “Influence of dry-cleaning on physical and mechanical properties of wool/ acrylic fabrics”. The 2/2 twill weave samples of wool/ acrylic blended fabrics (pure wool, 80/20 and 30/70) were dry cleaned up to 5, 10 and 15 times to know the effect of dry-cleaning on functional properties. The study revealed that, the strength and elongation of wool/ acrylic blended fabrics reduced significantly with increase in wool fibre ratio in the blend. Drape and smoothness of wool/ acrylic blended fabrics enhanced after dry-cleaning. By contrast, crease recovery of the dry-clean fabrics has been reduced and the fabric thickness has increased due to shrinkage.

Pant and Sharma (2012) carried out a research on “Performance of camel kid hair: acrylic blended yarn and knitted fabric”. Camel hair was blended with acrylic in two ratios *viz.*,, 75/25 and 50/50 on khadi hand spinning system. The plain knitted fabric samples were prepared on 6 gauges, 14 inch diameter circular knitting machine and the properties were assessed. The knitted fabric produced by 75/25 blended yarn exhibited higher strength, thermal insulation, abrasion resistance, knitting performance and hand than 50/50 blends.

Sharma and Pant (2013) reported on “Camel hair/ Merino wool blended knitted fabrics”. The camel hair was blended with Merino wool in 25/75, 75/25 and 50/50 ratios on khadi spinning system and fabrics were knitted on 6 gauge circular hand knitting machine. The study concluded that, all the blended fabrics showed higher thickness as compared to pure Merino wool fabric. The air permeability decreases in the blended fabrics. Blending of camel hair with Merino wool adversely affects the hand of the fabrics as the percentage of camel hair was increased, the hand of the blended fabrics deteriorated. Thus it can be concluded that, blending of Merino wool improves hand and feel of the fabric.

Sharma and Pant (2013) studied on “Properties of camel kid hair: Chokla wool blended yarns and fabrics”. Camel hair was blended with Chokla wool in three ratios *viz.,* 25/75, 75/25 and 50/50 respectively on Khadi hand spinning system. The blended yarns were further used for production of knitted fabrics on circular hand knitting machine. The study revealed that camel hair/ Chokla wool (75/25) knitted fabric performed better properties in terms of strength, abrasion resistance and warmthness than the other blends.

Naebe and McGregor (2013) investigated on “Comfort properties of superfine wool and wool/ cashmere blend yarns and fabrics”. The comfort properties of yarns and single jersey knitted fabrics made of pure superfine wools and wool/ cashmere blends were assessed. Notched template assisted the rapid testing of yarns to predict the comfort properties of fabric made from these yarns using the Wool Comfort Meter (WCM). The results indicated that both the cashmere blend ratio and fibre crimp

of wool affected the measured comfort properties of yarns. The fibre attributes which significantly affected the Wool Comfort Meter of the yarns were mean fibre diameter and the number of medullated fibres. The study concluded that predicting the comfort properties of fabric by assessing yarns, offers designers a way of manipulating the comfort properties of wool knitwear.

A study on "Value addition of Mulberry silk waste/ wool blends to develop handloom fabrics" was carried out by Verma *et al.* (2013). The blend proportion of 65/35 (silk waste/ wool) was spun into 30s and 40s metric count (Nm) yarns and employed for production of twill woven fabrics. Two fabrics were developed using blended yarns of 2/30s warp and single 30s weft (S_1) and 2/40s warp and single 40s weft (S_2) respectively. Further, two union fabrics (S_3) and (S_4) were developed using pure wool in warp and blended yarns in weft. The blended fabrics exhibited excellent drapability, lesser bending length and flexural rigidity and higher abrasion resistance. The union fabrics (S_3) and (S_4) showed excellent crease recovery, better dimensional stability, good thermal insulation, high breaking and tear strength than the blended fabrics.

Sharma and Pant (2015) reported on "Handle of cotton: wool knitted khadi fabric". The blended yarns were prepared by blending Indian crossbred wool (Rambouillet and Chokla) with cotton in three different proportions *viz.,* 10/90, 20/80 and 30/70 respectively. The fabric handle of the double jersey fabric samples which were developed on 10-12 gauge flat bed hand knitting machine were assessed objectively by SiroFAST. Among the fabrics pure cotton and cotton-wool (90/10, 80/20 and 70/30) blended fabrics showed warning to garment maker in terms of greater per cent warp relaxation shrinkage of knitted fabrics. As the warp and weft extensibility was high, care is needed in laying up of fabrics. Also the fabrics require pinning as the shear rigidity was low.

Sharma and Pant (2016) conducted a study on "Development of cotton: wool knitwears on khadi system and evaluation of their acceptability". The cotton fibres were blended with wool in three proportions *viz.,* 90/10, 80/20 and 30/70 respectively and further the double jersey knit fabrics were prepared on flatbed hand knitted machine of 10-12 gauge. Six prototypes of three ladies garments were designed and developed which include sweater, top and jacket. Three dyed yarn and three dyed fabric garments were prepared. The acceptability of designed khadi garments were assessed using three point rating scale. It was found that the top of cotton/ wool (90/10) got highest preference in yarn dyed garments and sweater of cotton/ wool (80/20) has been most accepted in case of fabric dyed garments by consumers. It was concluded that all developed khadi garments were accepted by respondents.

3. MATERIAL AND METHODS

The present investigation titled 'Quality assessment of UAS sheep breed wool blends' was carried out at the Department of Textile and Apparel Designing, College of Rural Home Science, University of Agricultural Sciences, Dharwad during the year 2014-16.

This chapter helps the investigator to plan the research work to be carried out meticulously. The details of various material used, processes involved, products developed and the quality parameters assessed are presented in this chapter that are classified under the following subheadings:

3.1 Selection of the sample

- 3.1.1 UAS sheep breed wool
- 3.1.2 Synthetic and natural fibres
- 3.1.3 Fibre properties

3.2 Processing of UAS sheep breed wool

- 3.2.1 Shearing of UAS sheep breed wool
- 3.2.2 Fibre opening and dusting
- 3.2.3 Fibre scouring and drying
- 3.2.4 Pre-carding

3.3 Development of pure UAS sheep breed wool and blended yarns

- 3.3.1 Fibre blending
- 3.3.2 Carding
- 3.3.3 Spinning
  - 3.3.3.1 Method of spinning
    - 3.3.3.1.1 Hand spinning
    - 3.3.3.1.2 Friction spinning

3.4 Assessment of physical properties of pure UAS sheep breed wool and blended yarns

- 3.4.1 Yarn count (Nm)
- 3.4.2 Yarn twist (tpi)
- 3.4.3 Single yarn strength (kgf) and elongation (%)
- 3.4.4 Yarn evenness

3.5 Development of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

3.6 Assessment of mechanical properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

- 3.6.1 Cloth count (Numerical expression)
- 3.6.2 Cloth weight (GSM)
- 3.6.3 Cloth thickness (mm)
- 3.6.4 Cloth crease recovery angle (degree)
- 3.6.5 Cloth stiffness (cm)

3.7 Assessment of functional properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

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

3.7.2 Cloth drapability (%)

3.7.3 Cloth abrasion strength (cycles)

3.7.4 Cloth pilling (ratings)

3.7.5 Cloth air permeability (cm^3 / cm^2 / sec)

3.7.6 Cloth thermal insulation value (tog)

3.8 Variables included for the study

3.8.1 Dependent variable

- Functional properties

3.8.2 Independent variable

- Mechanical properties

3.9 Cost of production of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

3.10 Statistical tools

3.11 Hypothesis set for the study

3.1 Selection of the sample

3.1.1 UAS sheep breed wool

The triple crossed UAS (University of Agricultural Sciences) sheep breed wool fibres were collected in autumn clip from the Department of Animal Sciences, UAS, Dharwad (Plate 1).

3.1.2 Synthetic and natural fibres

The jute, recycled polyethylene terephthalate (r-PET) and acrylic fibres were procured from Wool Research Association (WRA), Thane, Mumbai (Plate 2).

3.1.3 Fibre properties

The properties of the selected fibres, *viz.,* fibre length, fibre diameter, tenacity and elongation percentage are presented in Table 1.

Criteria for selecting UAS sheep breed wool fibres

The UAS sheep breed is mainly using for meat purpose and the wool fibres are hardly used by the kambli weavers in the local area due to lack of strength and least elasticity compared to local Deccani and Bannur breeds. Hence to improve the strength and add value to the fibre, the research has been designed (Fig. 2).

Criteria for selecting the recycled polyethylene terephthalate (r-PET), acrylic and jute fibres

- The recycled polyethylene terephthalate/ wool blends are universal accepted due to higher strength, comfort nature and durability of the products
- Acrylic is more versatile and are highly compatible with wool fibres
- A trial attempted to explore the spinnability of the jute/ wool blends



Plate 1. UAS sheep breed



2.1 UAS sheep breed wool fleece



2.2 Acrylic fibres



2.3 r-PET fibres



2.4 Jute fibres

Plate 2. Synthetic and natural fibres used in the study



Plate 3. Shearing of UAS sheep breed wool fleece



Plate 4. Opening and dusting of UAS sheep breed wool

Table 1: Fibre properties

Sl. No.	Test parameters	Wool	r-PET	Acrylic	Jute
1	Fibre diameter (micron)	30.54	12.61	11.81	39.65
2	Fibre length (mm)	45.00	60.00	60.00	75.00
3	Fibre tenacity (gm/denier)	3.88	3.73	5.97	4.11
4	Fibre elongation (%)	30.00	13.23	18.62	2.27

3.2 Processing of UAS sheep breed wool

3.2.1 Shearing of UAS sheep breed wool

Sheep shearing is a process of separation of wool fleece from the lamb. Prior to clipping, the sheep's were bath with water to remove the impurities and to make the shearing process easier. The shearer hold the individual sheep tightly in between his legs and the fleece were shorn with electrically operated wool shearing machine, which shear closer and faster. During shearing process, each fleece was examined for removing of discolored and contaminated fleece.

The shearing process was carried out at Department of Animal Sciences, University of Agricultural Sciences, Dharwad and the fleece was further utilized for wool processing (Plate 3).

3.2.2 Fibre opening and dusting

Wool fibre processing *viz.,* opening, scouring and pre-carding was carried out at Wool Development and Research Centre, Ranebennur, Haveri district, Karnataka.

Greasy wool was opened to facilitate the removal of fibre entanglement, foreign matter and to assist the scouring processes effectively. Required quantity of fleece was fed in to fibre opener and duster machine. This machine works with the principle of blow room, where the air is circulating at constant speed which helps to open up the fibre entanglement and separation of foreign material present in the fibres. The cleaned and opened fibres were dusted out of the machine. The cleaned and dusted fibres were further used for scouring (Plate 4).

3.2.3 Fibre scouring and drying

Traditionally wool was scoured in hot aqueous solution of soap and alkali. The conventional aqueous scouring removes the wool grease in emulsion, the suint in solution and the dirt in suspension. Commercial wool scouring machine comprised of two wash bowls and squeeze heads, usually linked to an in-line squeezer semi dryer (Plate 5). The typical conventional scouring lines include two bowls having rake or harrow mechanisms that dunk and transport the wool. The cleaned and opened wool fibres were fed into the scouring lines *i.e* first bowl with alkaline treatment and second bowl with soaping treatment. Finally scoured fibres were passed between the squeeze rollers to remove the excess moisture present in the fibre mass. The squeezed wool mass was collected at the end of the machine and shade dried. The following recipe was used for wool scouring.

Recipe :

Wool	: 50 kg
M:L Ratio	: 1:40
Sodium carbonate	: 3 per cent owm
Soap oil	: 2 per cent owm
Temperature	: 45^0 C
Time	: 4 hours

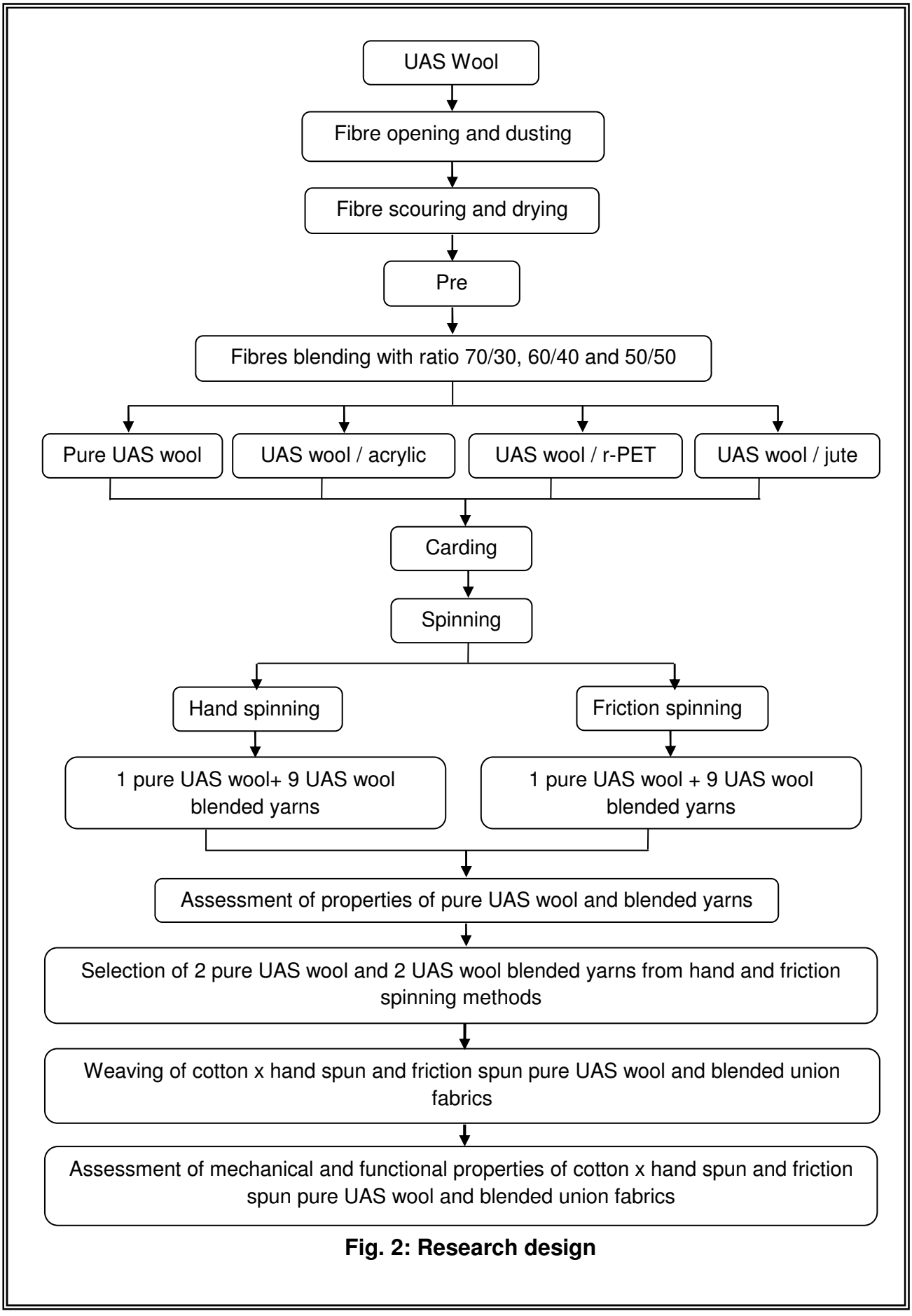


Fig. 2: Research design



Plate 5. Two bowl scouring of UAS wool fibres



Plate 6. Pre-carding of UAS wool fibres

3.2.4 Pre-carding

Good opening and cleaning of the wool prior to carding are beneficial, the pre carding operation involves blending and opening of fibres (Plate 6). The wool web was fed into the carding machine, where the initial straightening and the separation of short staple fibres takes place. The pre carded lap was further used for production of UAS sheep breed wool pure and blended yarns (Plate 7).

3.3 Development of pure UAS sheep breed wool and blended yarns

In order to improve the spinnability and to enhance the value of UAS sheep breed wool, it was blended with acrylic, recycled polyethylene terephthalate and jute fibres in varied proportion *viz.,* 70/30, 60/40 and 50/50.

3.3.1 Fibre blending

Blending refers to the sequence of process required to convert two or more kinds of staple fibres into a single yarn composed of a mixture of the component fibres.

The conventional sandwich/ stack blending method was adopted to develop blended yarns. In this method, the fibres were measured in varied proportion on electronic weighing balance. According to blend ratio, the conditioned fibres were layered on one over the other and the layered fibre mass was thoroughly mixed by hand. The blended web was further used for spinning (Plate 8).

3.3.2 Carding

The carding (Plate 9) is mainly carried out to straighten the fibres and to remove the short staple fibres from the mass. The woolen carding system used for carding of the blended fibres consists of two parts or sections, namely the scribbler (breaker card) and carder (finisher card), there typically being two cylinders (swifts), each with a doffer (and four or five pairs of worker and stripper rollers) in each section. The opening and disentanglement of tuffs takes place correspondingly in the carding unit, made up of a breast clothed with metallic wire with workers and strippers. After the scribbler, the fibrous web passed through crush (Peralta) rollers placed at the end of the scribbler section, which crush the vegetable matter (Simpson and Grawshaw, 2002). Finally carded web passed through cylinder, worker stripper and doffer, where the thin sliver was found (Plate 10).

3.3.3 Spinning

Ultimate aim of spinning is to produce yarn of required linear density and which has good evenness, better strength and a minimum number of faults. The spinning was carried out at Wool Research Association, Thane, Mumbai (WRA). The pure and blended slivers were processed on woolen spinning system.

3.3.3.1 Method of spinning

3.3.3.1.1 Hand spinning

The hand spinning is most commonly used spinning method in the study area mainly to support the hand spinners and to encourage the traditional kambli weavers, who adopt the hand spinning technique for the development of kamblis in the local areas.



Plate 7. Pre-carded sliver of UAS sheep breed wool fibres



Plate 8. Sandwich/stack method of blending UAS sheep breed wool fibres



Plate 9. Feeding UAS sheep breed wool blended fibres in to the woolen card



Plate 10. Carded sliver of the UAS sheep breed wool blends

The pure and blended woolen rove sliver was spun on hand charaka at Medleri, Ranebennur taluk, Haveri district, Karnataka. The village was purposively selected for the spinning of wool in this study, wherein majority of the population are shepherds and wool weavers. Of 200 families living in the Medleri village, about 100 families are sheep farmers whose men and women are engaged in weaving woolen blanket in traditional style. 98 per cent of the people owned charaka as their livelihood is sheep rearing, yarn preparation, warping and kambli preparation (Mariyappanavar *et.al,* 2014).

Majority of women involve in hand spinning of wool fibres using hand charaka. Women take the tuft of wool fibres in her left hand and slowly leaves the wool fibre by twisting the fibres with the fingers and simultaneously rotates the charaka wheel by right hand. As the wheel starts rotating, the spindle placed on the charaka spins, which winds the hand twisted yarns tightly on the spindle. A woman could spin 0.75 kg of yarn per day on an average using hand charaka (Plate 11).

3.3.3.1.2 Friction spinning

The laboratory trials were conducted at Wool Research Association (WRA), Thane, Mumbai for blending yarns. The institute has pilot plant of woolen carding system and friction spinning machine. Hence the friction spinning method was selected for the spinning of the blended yarns.

The friction spinning system (Plate 12) has been modified and is identified as DREF II, a variation of the open-end spinning process. The principle of the technique is that a stream of carded fibres pass along the longitudinal drum axis in the roll nip of the perforated drums both moving in the same direction (Plate 13). This action forces the fibres to be wedged along the nip, thereby compressed; the friction of the rollers cause the fibres to twist around each other. The process utilizes a current of air to transport the carded fibres to the longitudinal nip region of the two drums. Parallel orienting disks along with fingers are used to align the fibres in the take-off direction of yarn to improve parallelization. The air stream gives the sliver end, the initial twist as it presses the disentangled fibres against the continuously forming yarn compound wedged into the roll nip. Air suction through the perforated drums produces a uniform twist effect as the yarn is drawn off the end of the drums (Plate 14). The amount of twist may be controlled by regulating the suction. The yarn count is determined by the thickness of the wedge in the yarn-forming nip and the width of the nip itself.

There are certain advantages of DREF II system. The low cost of fibre preparation as the direct feed of card slivers to the spinning zone. The high-speed elements required for ring and rotors spinning are eliminated. Yarn breakage during spinning is avoided because there is no tension in the spinning area.

3.4 Assessment of physical properties of pure UAS sheep breed wool and blended yarns

3.4.1 Yarn count (Nm)

The count of yarn is a numerical expression which defines its fineness. A number indicating the mass per unit length or the length unit mass of yarn. Yarn count was expressed in metric system (Nm). It is indirect system of yarn count where the yarn count is the number of ‘unit of length’ per ‘unit of weight’. The length unit is kilometer and weight unit is kilogram. Yarn count can be calculated by the formula:



Plate 11. Hand spinning of UAS sheep breed wool blended yarns in charaka



Plate 12. A view of friction spinning machine



Plate 13. Feeding the UAS sheep breed wool blended sliver into the friction spinning machine



Plate 14. Friction spinning of UAS sheep breed wool blended yarns

$$\text{Count (Nm)} = \frac{\text{Length in meters}}{\text{Weight in grams}}$$

Length of specimen = 1 meter

Number of specimen tested = 10

Name of instrument = Electronic weighing balance

3.4.2 Yarn twist (tpi)

Twist is the spiral deposition of the components of the thread which is usually the result of relative rotation of the two ends. The direction of twist is indicated by the use of the letters S or Z. With the increase in twist, the yarn strength gradually increases till it reaches maximum and then further increase leads to decrease in strength of yarn. Yarn twist is expressed in terms of twist per inch (tpi) or twist per meter (tpm).

Length of specimen	:	10 inch
Number of specimen tested	:	10
Name of instrument	:	Twist tester
Twist direction	:	Z

3.4.3 Single yarn strength (kgf) and elongation (%)

The strength of single yarn is a measure of its resistance to the gradually increasing force. It is usually expressed in terms of tenacity. Tenacity is defined as the mass stress at break and is ratio of breaking strength in gf to linear density in tex units. Hence its unit is kg/ tex.

Elongation is the increase in length of the specimen from its initial length expressed in units of length. The distance that material will extend under a given force is proportional to its original length, hence elongation is quoted as strain or percentage extension. The pure and blended yarns extension percentage was assessed.

The breaking strength of the yarn determined is usually taken as an index of yarn quality and is expressed either in grams or pounds. The specimens were tested as per ASTM D2256.

Pure UAS sheep breed wool and blended yarns were tested for the single yarn using experimental details given below:

Equipment	:	MAG Unistretch 250
Working principle	:	Constant rate of extension (CRE)
Rate of elongation	:	100
Elongation limit	:	100
Force limit	:	50
Gauge length	:	200 mm
No. of observation	:	10

3.4.4 Yarn evenness

Yarn evenness is the measure of variation in weight per unit length of the yarn or as the variation in its thickness (Plate 15). Evenness of a yarn decides the quality of the ultimate fabric. Pure and blended yarns produced in the present study were assessed for yarn evenness the particulars of which are as below:

Equipment	:	Uster Tester 4-SE
Working principle	:	Capacitance type by changing the dielectric constant
Specimen length	:	1 km
No. of observation	:	05

3.5 Development of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Hand spun and friction spun pure UAS sheep breed wool yarns were used as control and one blended yarn was selected from each spinning system based on the yarn strength and yarn evenness.

The selected pure wool and blended yarns were used as a weft and 2 ply 20s count cotton yarn was used as warp for development of cotton x pure UAS sheep breed wool and blended yarns. The union fabrics were woven on a handloom at the Khadi Handloom Development Centre (KHDC), Narasapura weaving cluster at Gadag.

Constructional details of UAS sheep breed wool blended union fabrics included general information about the constructional parameters of fabrics pertaining to loom employed, yarn type, twist direction, twist per inch, threads per inch and weave type (Table 2).

3.6 Assessment of mechanical properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

3.6.1 Cloth count (Numerical expression)

Cloth count in woven textile material is the number of ends and picks per unit area while the fabric is free from wrinkles and is affected by the yarn count and compactness of the weave.

The number of warp and weft yarns in one sq. inch of the fabric is counted at ten randomly selected places across the width and along the length of the test specimens. The region near the selvedge should be avoided because the spacing of thread is often a little different than in the body of the cloth (Booth, 1996). Further, mean values of ends and picks per inch were calculated.

Number of specimen tested	:	10 each warp and weft
Method	:	Direct counting of threads per unit area, 1 inch
Instrument used	:	Magnifying counting device, the pick glass



Plate 15. Yarn evenness testing of the pure UAS sheep breed wool and blended yarns

Table 2. Constructional details of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Union fabrics	Direction	Fibre content	Yarn type	Twist direction	Yarn count	Threads per inch	Weave type
1	Cotton	Warp	Cotton	2 ply	S	20s	59	2/2 Twill
	Hand spun pure UAS sheep breed wool	Weft	UAS sheep breed wool	Single	Z	2.26	16	
2	Cotton	Warp	Cotton	2 ply	S	20s	60	2/2 Twill
	Handspun UAS sheep breed wool/ r-PET (70/30)	Weft	UAS sheep breed wool /r-PET (70/30)	Single	Z	3.76	17	
3	Cotton	Warp	Cotton	2 ply	S	20s	58	2/2 Twill
	Friction spun pure UAS sheep breed wool	Weft	UAS sheep breed wool	Single	Z	7.61	22	
4	Cotton	Warp	Cotton	2 ply	S	20s	60	2/2 Twill
	Friction spun UAS sheep breed wool/ jute (60/40)	Weft	UAS sheep breed wool /jute (60/40)	Single	Z	9.92	23	

3.6.2 Cloth weight (GSM)

The weight of a fabric can be described in two ways, as either the 'weight per unit area' or 'weight per unit length'. In the fabric description, 'weight per unit length is usually referred to as 'weight per running yard'. The specimens were tested as per IS 1964:2001.

A sample size of 25 x 25 cm is cut and weighed on an electronic weighing balance to determine the weight per square meter (g). In addition, a sample size of 5 x 5 cm is cut where warp and weft threads are separated and weighed to calculate the percentage composition of warp and weft using the following formula. It is expressed in gram per square meter (GSM).

Weight of 5 x 5 cm sample	=	a g
Weight of warp yarns	=	b g
Weight of weft yarns	=	c g
Per cent of warp	=	100 x b/a
Per cent of weft	=	100 x c/a
Number of specimens tested	=	05
Instrument used	=	Electronic weighing balance

3.6.3 Cloth thickness (mm)

The precise measurement of the distance between two plane parallel plates when they are separated by the cloth, a known arbitrary pressure between the plates being applied and maintained. The test specimen should be free from folds, wrinkles, crushing or distortion and abnormal to test material (Booth, 1996). The specimens were tested as directed in ASTM test method D: 1777-1975.

The average thickness of the material is determined by observing the linear distance that a movable plane is displaced from a parallel surface by the textile material while under a specified pressure.

The specimens taken were free from folds, wrinkles crushing or distortions, abnormal to test material. Place the specimen on anvil of the test apparatus, bring the pressure foot into contact with the opposite side of the material and record the thickness in milimeter (mm).

Shape of the anvil	:	Round
Area of the anvil	:	1 cm diameter
Shape of the pressure foot	:	Round
Number of specimen tested	:	10
Name of the instrument	:	Shirley's thickness tester

3.6.4 Cloth crease recovery angle (degree)

The samples were tested as per the direction of AATCC test method 66-1975. The test sample was creased for a definite period of time at a known load and then allowed to recover or to regain its crease. The recovery was measured in terms of the extent of angle to which it has been recovered.

Size of the specimen	:	5 x 2.5 cm
Weight / load applied	:	2 kg
Creasing period	:	5 min
Recovery period	:	5 min
Number of specimen tested	:	5 each warp and weft
Name of the instrument	:	Crease recovery tester

Further, cloth crease recovery is determined by using the formula,

Cloth crease recovery = √Warp way angle x √Weft way angle

3.6.5 Cloth stiffness (cm)

Cloth stiffness is the resistance of the fabric to bending. Bending length is the length of the fabric that bends under its own weight to a definite extent. It equals half the length of rectangular strip of fabric that bends under its own weight to an angle of 41.5º. It is equal to the length of a rectangular strip of material that bends under its own weight to an angle of 7.1º. The test samples were tested as directed in BS test methods: 3356-1961.

Place the test samples on the platform with the scale on top of it, length wise and the zero of scale coinciding with the leading edge of the test sample. Start pushing the sample along with the scale slowly and steadily when the leading edges project beyond the edges of the platform. An increasing part of the sample overhangs and starts bending on its own weight. When two inclined lines (of the inclined plane making an angle of 41.5º with the horizontal) of the tester coincide, record the length of the over hanging from the scale.

Four readings from each sample with each side up are taken

Size of the sample	:	25 x 2.5 cm
Number of samples tested	:	One with four readings (both warp and weft way)
Name of the instrument	:	Shirely's stiffness tester

Further, the bending length was calculated by using formula,

Bending length = L / 2 cm

Where L is the mean length of the overhanging portion in cm

3.7 Assessment of functional properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Functional properties are the product of mechanical properties *i.e*. functional properties of any textile material is sonly dependent on the mechanical properties, where mechanical properties in turn depend upon several other factors like type of yarn, fabric geometry etc of the several functional properties durability of the fabric is of prime importance, following are the functional properties assessed for the union fabrics:

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

Tensile strength is the breaking strength of a sample *i.e*. ability of the material to withstand the rupture induced by external forces. It is usually expressed in units of force per unit of cross sectional area of the sample.

Elongation is the increase in length of the specimen from its starting length expressed in units of length. The distance that a material will extend under a given force is proportional to its original length; therefore elongation is quoted as strain or percentage extension (Saville, 2004). It is expressed in kilogram force (kgf).

The elongation that a specimen undergoes is proportional to its initial length. Strain expressed the elongation as a fraction of the original length.

The specimens were tested as directed in ASTM D2256. The method employed to determine the breaking load and elongation of the material by using the 'raveled strip test' in "Unistretch 250" tensile tester. The specimen is 5 cm wide piece of fabric prepared initially by cutting the material to a width of about 7 cm and ravelled the threads from both sides until the width attained 5 cm. The test length is 20 cm in between the jaws and extra length was taken to grip within the jaws.

Size of the specimen	:	20 X 5 cms
Number of specimen tested	:	05
Test method	:	Raveled strip test
Load range	:	250 kgf
Speed	:	300 mm/ min
Name of the instrument	:	MAG Unistretch 250

3.7.2 Cloth drapability (%)

Drape is the ability of a fabric to assume a graceful appearance in use. It is the extent of which a fabric deforms when it is allowed to hang under on its own weight to the extent.

Drape coefficient is the area covered by the shadow of the draped specimen expressed as percentage of the area of annular ring of the fabric.

A specimen is cut by circular template and is kept on supporting disc of the drape meter. On switching the lamp, it gives the shadow of draped area, which is taken on a paper and is weighed. Similarly draped shadow area of the template and supporting disc is also taken. Thus drape coefficient is calculated by using the formula:

$$F = \frac{A_s - A_d}{A_D - A_d}$$

Where,

F	=	Drape co-efficient
A_s	=	Area of the shadow
A_d	=	Area of the supporting disc
A_D	=	Area of the template
Size of the specimen	=	30 cm diameter
Name of the instrument	=	Eureka drape meter

3.7.3 Cloth abrasion strength (cycles)

Abrasion is aspect of wear. 'Wear' is the net result of a number of agencies which reduces the serviceability of an article. Abrasion is the rubbing away of the component fibres and yarns of the fabric. The specimens were abraded as directed under IS test method 12673:1989.

The specimen's were abraded until a hole was formed and number of cycles to create a hole was recorded.

Size of the specimen	:	13.5 cm (diameter)
Number of specimen tested	:	04
Type of abradant	:	Zero emery paper
Type of abrasion	:	Multidirectional
Determination of end point	:	Formation of hole
Name of the instrument	:	Martindale's abrasion tester

3.7.4 Cloth pilling (Ratings)

Pilling is a fabric surface fault characterized by little pills. Pills are balls or bunch or entangled fibres clinging to the cloth surface and giving the garment an unsightly appearance. This method covers the determination of resistance to the formation of pills and other related surface changes on textile fabric.

The specimens were tested as directed in IS test method: 10971-1984.

A fabric sample measuring 5 x 6 sq. inch is sewn so as to fit firmly when placed around a rubber tube of 5 inch length, 1 ¼ inch outside and 1/ 8 inch thick, which is then rotated for 5 hours to complete 18,000 revolutions at the rate of 60 revolutions/ min.

After tumbling, the extent of pilling is assessed visually by comparing with the arbitrary standards – 1, 2, 3, 4 and 5.

Rating scale

1 - No pilling

2 - Slight pilling

3 - Moderate pilling

4 - Severe pilling

5 - Very severe pilling

Size of the specimen - 12.5 x 12.5 sq. inch

Name of the instrument - ATC pilling tester

3.7.5 Cloth air permeability (cm^3 / cm^2 / sec)

Air permeability is defined as the volume of air measured in cubic centimeters passed per second through 1 cm^2 of the fabric at a pressure of 1 cm of water.

All the samples were tested as directed by ASTM D 737. Air at standard atmosphere is drawn from the laboratory through the test specimen by means of a suction pump, the rate of flow being controlled by means of the bypass valve and series valve at the definite pressure. The rate of flow is adjusted until the required pressure drop across the fabric and is indicated on a drought gauge. The rate of flow of air is then recorded by rotameters from the instrument.

Number of specimen tested : 05

Area of specimen exposed : 38 sq. cm

Pressure differential : 125 Pa

Name of the instrument : FX 3300 LabAir IV

3.7.6 Cloth thermal insulation value (tog)

The thermal insulation of fabric is expressed in tog units, where 1 tog corresponds to a heat transfer to 10 wm^{-2} (watt per meter square) per degree temperature difference. Higher the tog values, greater is the insulation

All the samples were tested as directed in ASTM test method D: 1518-1985. The experiment was carried out at atmosphere condition of 65 ± 2 per cent RH and 27 ± 2^0C temperature.

The instrument used for assessing thermal insulation of fabrics consists of a small chamber where it employees a hot plate on which the specimen is mounted. The temperature of the hot plate is maintained equal to human skin temperature by supplying continuous power to the instrument. This hot plate is surrounded with a square strip known as guard plate whose temperature is slightly higher than the hot plate. An air gap is maintained between the hot plate and the specimen. The heat from the hot plate is absorbed by the fabric, there after decreasing the temperature of the hot plate, thus demanding for additional power supply. The power consumed Q_d to maintain the temperature of large hot plate is noted from the instrument. More the power consumed, lesser is the thermal insulation of a fabric.

Size of the specimen	:	12 cm x 12 cm
Size of the hot plate	:	10 cm x 10 cm
Temperature of the hot plate	:	33^0C
Temperature of the guard plate	:	33.5^0C
Air gap between hot plate and the specimen	:	1 cm
Method employed	:	Guarded hot plate method
Duration of the test	:	30 min
Number of specimen tested	:	05
Name of the instrument	:	Kawabata thermolabo II

3.8 Variables included in the study

3.8.1 Independent variable

- Cloth count (Numerical expression)
- Cloth thickness (mm)
- Cloth weight (GSM)
- Cloth stiffness (cm)
- Cloth crease recovery (degree)

3.8.2 Dependent variable

- Cloth tensile strength (kgf) and elongation (%)
- Cloth abrasion strength (cycles)
- Cloth drapability (%)
- Cloth pilling (ratings)
- Cloth air permeability (cm^3 / cm^2 / sec)
- Cloth thermal insulation value (tog)

3.9 Cost of production of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The variable cost of the developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics were estimated for comparison.

3.10 Statistical tools used

The experimental results of the pure UAS sheep breed wool and blended yarns obtained were subjected to Two-way ANOVA by implying the Control Random Design (CRD) and the properties of union fabrics were analyzed by One-way ANOVA.

Coefficient of determination (R^2)was calculated to know the effect of mechanical properties on functional properties using the formula,

$$R^2 = \frac{\text{Sum of squares due to multiple regression}}{\text{Total sum of squares}}$$

To know the individual effect of all the independent variables on the dependent variable multiple regression was carried out using the formula,

$Y = a+b_1x_1+b_2x_2+----------+b_nx_n$

$x_1.x_2.----------x_n =$ Independent variables

$b_1.b_2.----------b_n =$ Dependent variables, (Regression coefficients)

3.11 Hypothesis set for the study

1. The fibre content, blend ratio and method of spinning do not affect the yarn physical properties

2. The fibre content, blend ratio and method of spinning do not influence on the mechanical and functional properties of union fabrics

4. EXPERIMENTAL RESULTS

4.1 Development of pure UAS sheep breed wool and blended yarns

4.2 Assessment of physical properties of pure UAS sheep breed wool and blended yarns

4.2.1 Yarn count (Nm)

4.2.2 Yarn twist (tpi)

4.2.3 Single yarn strength (kgf)

4.2.4 Yarn elongation (%)

4.2.5 Yarn evenness

4.3 Development of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

4.4 Assessment of mechanical properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

4.4.1 Cloth count (Numerical expression)

4.4.2 Cloth weight (GSM)

4.4.3 Cloth thickness (mm)

4.4.4 Cloth crease recovery angle (degree)

4.4.5 Cloth stiffness (cm)

4.5 Assessment of functional properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

4.5.1 Cloth tensile strength (kgf)

4.5.2 Cloth elongation (%)

4.5.3 Cloth drapability (%)

4.5.4 Cloth abrasion strength (cycles)

4.5.5 Cloth pilling (ratings)

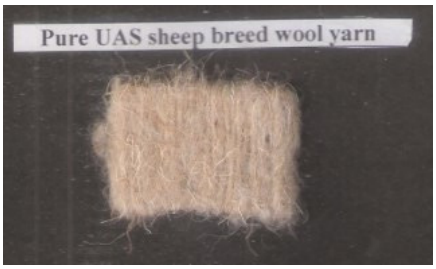
4.5.6 Cloth air permeability ($cm^3/cm^2/sec$)

4.5.7 Cloth thermal insulation (tog)

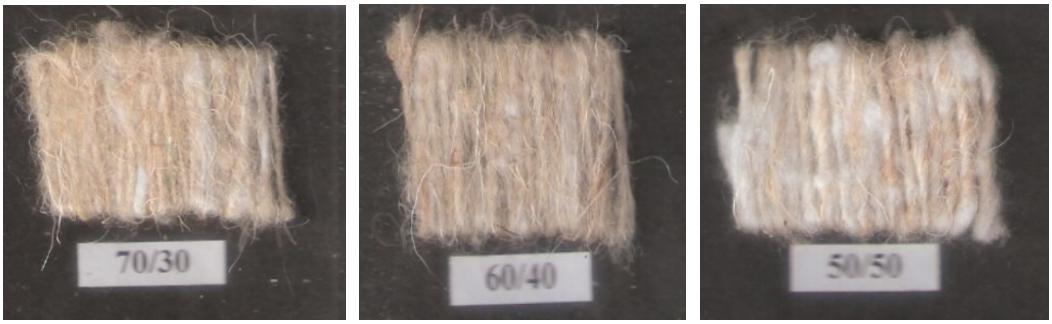
4.6 Cost of production of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

4.1 Development of pure UAS sheep breed wool and blended yarns

In order to improve the spinnability and enhance the value of UAS sheep breed wool, it was blended with acrylic, recycled polyethylene terephthalate (r-PET) and jute fibres in varied proportion *viz.,* 70/30, 60/40 and 50/50. The pure and blended slivers were subjected to hand and friction spinning systems. One pure wool and nine wool blended yarns with varied proportion were produced from hand spinning method (Plate 16). Similarly one pure wool and nine wool blended yarns with varied proportion were produced from friction spinning system (Plate 17). These developed pure UAS sheep breed wool and blended yarns were subjected to physical properties *viz.,* yarn count, yarn twist, single yarn strength and elongation and yarn evenness.



UAS sheep breed wool/acrylic blended yarns



UAS sheep breed wool/r-PET blended yarns



UAS sheep breed wool/jute blended yarns

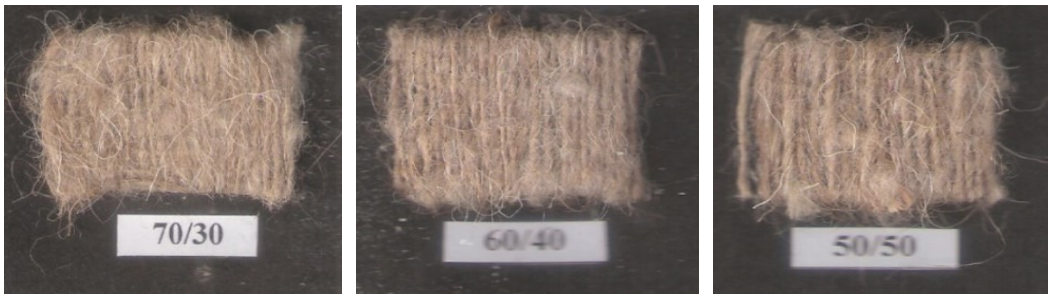
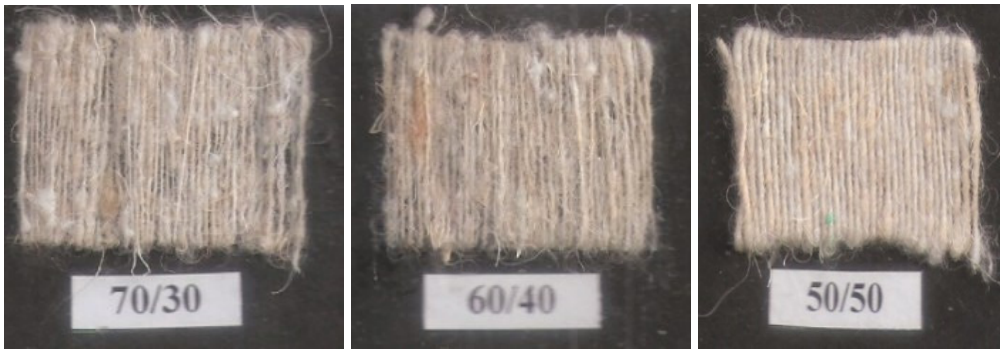


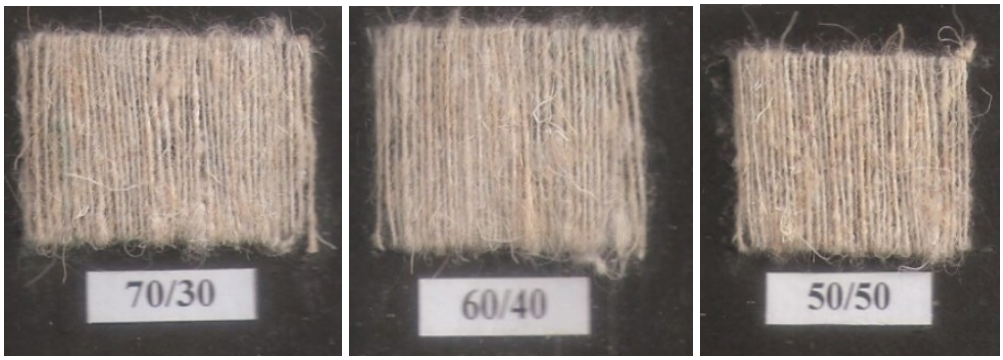
Plate 16. Hand spun pure UAS sheep breed wool and blended yearns



UAS Sheep breed wool/acrylic blended yarns



UAS Sheep breed wool/r-PET blended yarns



UAS sheep breed wool/jute blended yarns

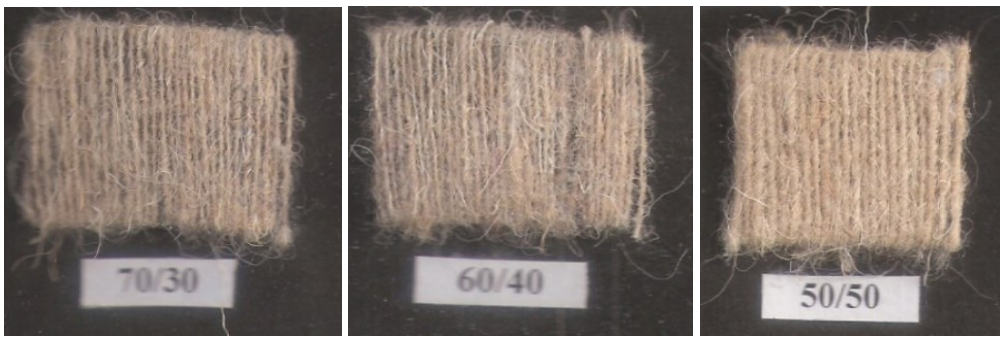


Plate 17. Friction spun pure UAS sheep breed wool and blended yarns

4.2 Assessment of physical properties of pure UAS sheep breed wool and blended yarns

The pure UAS sheep breed wool and blended yarns were subjected to study the physical properties by employing standard test methods.

4.2.1 Effect of blend ratio on yarn count (Nm) of the pure UAS sheep breed wool and blended yarns

Linear density or yarn count is a numerical expression which defines its fineness. The yarn count of the hand and friction spun pure UAS sheep breed wool and blended yarns were determined.

Yarn count of pure UAS sheep breed wool yarns were significantly higher than blended yarns with respect to method of spinning (A), fibre content (B), blend ratio (C) and interaction between A x B, B x C and A x C. Whereas, the combined interaction effect of A x B x C on yarn count of the pure UAS sheep breed wool yarns was non significant.

In general, hand spun pure UAS sheep breed wool and blended yarns possessed lower yarn count than the friction spun pure UAS sheep breed wool and blended yarns indicating hand spun yarns were coarser and bulkier than the friction spun yarns.

Irrespective of spinning methods, hand spun pure UAS sheep breed wool sample obtained least yarn count (2.26) than the rest of the yarns (Table 3 and Fig. 3).

Among the hand spun UAS sheep breed wool/ acrylic blended yarns, the yarn of 60/40 blend ratio exhibited finer yarn count (4.74) followed by 70/30 (4.39) and 50/50 (3.90). In case of friction spun blended yarns UAS sheep breed wool/ acrylic (70/30) blend ratio exhibited finer yarn count (13.08) than 60/40 (12.93) and 50/50 (5.91). In this group, as percentage of wool increases yarn becomes finer and vice versa.

Of the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarns, hand and friction spun yarns of 50/50 blend ratio depicted higher yarn count (6.48 and 10.94) followed by 60/40 (3.76 and 10.08) and 70/30 (3.34 and 9.66) respectively. In this case, finer yarns were obtained as the percentage of recycled polyethylene terephthalate (r-PET) increased and vice versa.

In the mixture of UAS sheep breed wool/ jute hand spun blends irrespective of blend ratio, a similar trend of yarn count was observed in all the samples *i.e.,* 2.97 (60/40), 2.78 (70/30) and 2.34 (50/50) respectively. Whereas in case of friction spun blended yarns as percentage of jute increases, yarns become coarser *i.e.,* the blend ratio of 70/30 (11.66), 60/40 (9.45) and 50/50 (4.90) respectively.

4.2.2 Effect of blend ratio on yarn twist (tpi) of the pure UAS sheep breed wool and blended yarns

Twist is the measurement of spiral turns given to a yarn in order to hold the constituent fibres or threads together. The effects of the twist are twofold: as the twist increases the lateral force holding the fibres together is increased so that more of the fibres can contribute to the overall strength of the yarn (Saville, 2004). Once the twist level attains maximum, the strength of the yarn falls down. Hence optimum twist level is very important in the yarn.

Table 3: Effect of blend ratio on yarn count (Nm) of the pure UAS sheep breed wool and blended yarns

Sl. No.	Fibres	Blend ratios	Yarn count (Nm)	
			Hand spun	Friction spun
1	UAS sheep breed wool	100 per cent	2.26	7.47
2	UAS sheep breed wool/ acrylic	70/30	4.39	13.08
		60/40	4.74	12.93
		50/50	3.90	5.91
3	UAS sheep breed wool/ r-PET	70/30	3.34	9.66
		60/40	3.76	10.08
		50/50	6.48	10.94
4	UAS sheep breed wool/ jute	70/30	2.78	11.66
		60/40	2.97	9.45
		50/50	2.34	4.90

ANOVA

Parameters	Sem ±	CD (5 %)	CV (%)
Method of spinning (A)	0.081	0.226*	14.661
Fibre content (B)	0.070	0.196*	
Blend ratio (C)	0.070	0.196^{NS}	
Method of spinning X Fibre content (A x B)	0.036	0.101*	
Fibre content X Blend ratio (A x C)	0.027	0.101*	
Method of spinning x Blend ratio (A x C)	0.325	0.909*	
Method of spinning X Fibre content X Blend ratio (A x B x C)	0.108	0.303*	

*Significant at 5 per cent level
NS- Non significant

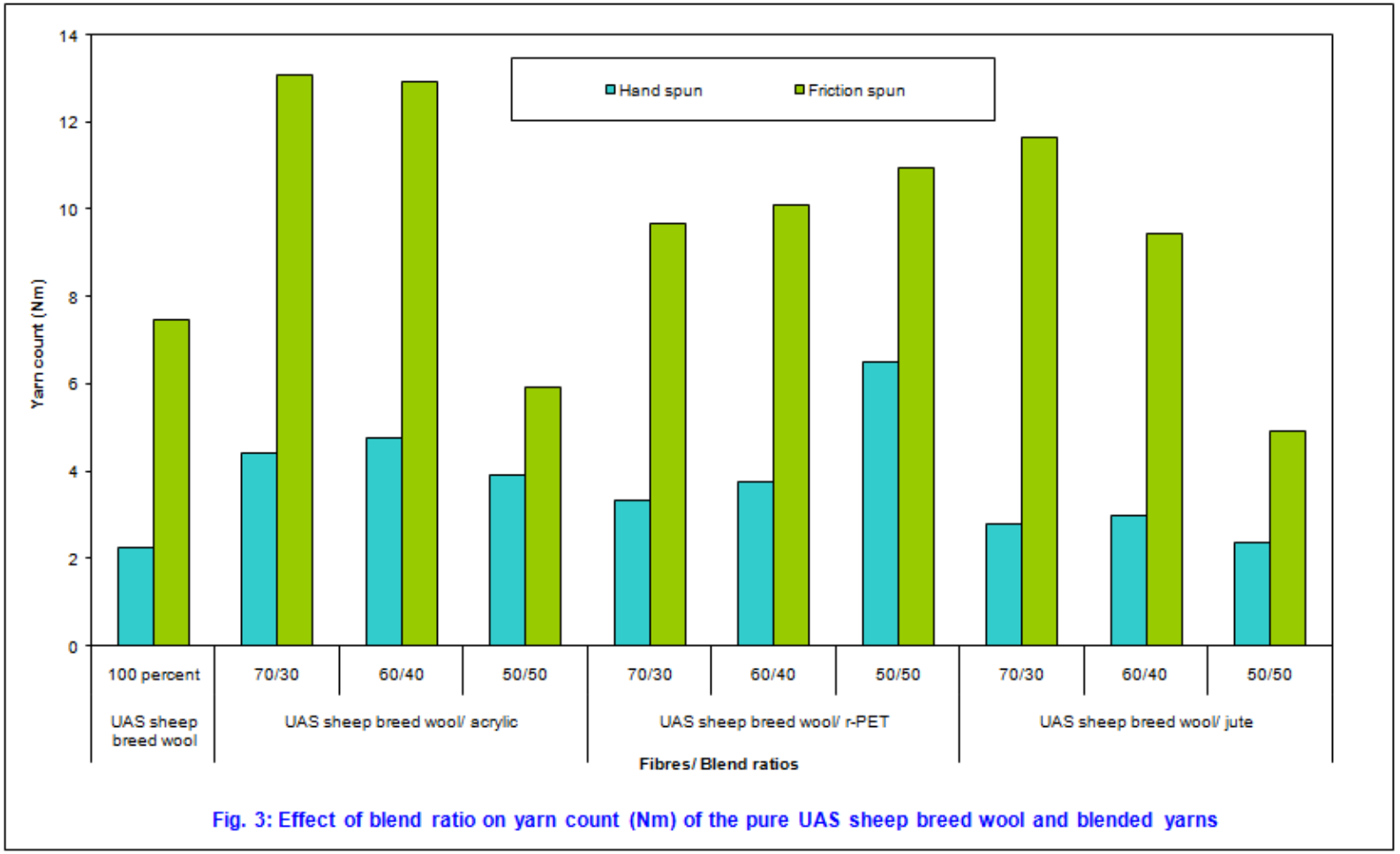


Fig. 3: Effect of blend ratio on yarn count (Nm) of the pure UAS sheep breed wool and blended yarns

Fig. 3: Effect of blend ratio on yarn count (Nm) of the pure UAS sheep breed wool and blended yarns

A significant difference was observed in the yarn tpi of pure UAS sheep breed wool and blended yarns with respect to method of spinning (A), fibre content (B), blend ratio (C) and interaction of A x B, B x C, A x C. Further the combined interaction effect of A x B x C on the yarn tpi of pure UAS sheep breed wool and blended yarns found to be significant (Table 4 and Fig. 4).

In general, higher tpi were observed in the friction spun yarns when compared to hand spun pure UAS sheep breed wool and blended yarns. A trend was seen in the friction spun yarns, the tpi increased with the increased jute, recycled polyethylene terephthalate (r-PET) and acrylic proportion in the blend ratio. But it was not clear in the hand spun blended yarns.

Among the hand spun yarns, the pure UAS sheep breed wool yarn showed least number of tpi (4.18) compared to other blends. In the hand spun yarns, the UAS sheep breed wool/ acrylic yarns exhibited greater tpi in all blend ratio 70/30 (7.20), 50/50 (5.68) and 60/40 (4.50) compared to recycled polyethylene terephthalate (r-PET) and jute blends. In case of friction spun blended yarns, UAS sheep breed wool/ acrylic 50/50 resulted higher tpi (9.88) than 60/40 (7.02) and 70/30 (5.10).

Of the hand spun UAS sheep breed wool / recycled polyethylene terephthalate (r-PET) blends possessed highest tpi in 70/30 (4.86) followed by 60/40 (4.42) and 50/50 (4.08). A trend of decrease in tpi with increase of recycled polyethylene terephthalate (r-PET) content in the blend was noticed. Whereas, friction spun UAS sheep breed wool / recycled polyethylene terephthalate (50/50) blend showed maximum tpi (13.04) than the 60/40 (12.44) and 70/30 (11.94).

Among hand spun UAS sheep breed wool/ jute blends, the 50/50 ratio possessed higher tpi (4.62) followed by 70/30 (4.30) and 60/40 (4.24) respectively. Further, in the friction spun blended yarns, greater tpi was observed in 50/50 (10.28) followed by 60/40 (7.70) and 70/30 (5.04). The least number of spiral turns were seen in the UAS sheep breed wool/ jute blends when compared to UAS sheep breed wool/ acrylic and UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends.

4.2.3 Effect of blend ratio on single yarn strength (kgf) of the pure UAS sheep breed wool and blended yarns

Yarn strength of UAS sheep breed wool blended yarns were found to be significantly higher than the pure UAS sheep breed wool with respect to method of spinning (A), fibre content (B), blend ratio (C) and interaction of A x B, B x C, A x C. The combined interaction effect of A x B x C on the yarn strength of pure UAS sheep breed wool and blended yarns found to be significant.

The hand and friction spun pure UAS sheep breed wool yarns exhibited comparatively low strength (0.26 and 0.25) than the blended yarns (Table 5 and Fig. 5).

In general, friction spun UAS sheep breed wool blended yarns showed lower strength than the hand spun UAS sheep breed wool blended yarns. Among the hand spun, UAS sheep breed wool/ acrylic blended yarns *i.e.,* 70/30 blend ratio attained highest tenacity value (0.52) followed by 60/40 (0.48) and 50/50 blend (0.44) respectively. Whereas in friction spun blended yarns, maximum strength was found in UAS sheep breed wool/ acrylic (50/50) blend ratio (0.55) as compared to 60/40 (0.27) and 70/30 (0.22).

The UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarn of 70/30 (0.62) and 50/50 (0.61) possessed greater strength than the 60/40 (0.55) blends. A mixed trend was observed in friction spun UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends *i.e.,* greater tenacity was noticed in 60/40 (0.39) followed by 70/30 (0.33) and 50/50 (0.30).

Table 4: Effect of blend ratio on yarn twist (tpi) of the pure UAS sheep breed wool and blended yarns

Sl. No.	Fibres	Blend ratios	Yarn twist (tpi)	
			Hand spun	Friction spun
1	UAS sheep breed wool	100 per cent	4.18	8.16
2	UAS sheep breed wool/ acrylic	70/30	7.20	5.10
		60/40	4.50	7.02
		50/50	5.68	9.88
3	UAS sheep breed wool/ r-PET	70/30	4.86	11.94
		60/40	4.42	12.44
		50/50	4.08	13.04
4	UAS sheep breed wool/ jute	70/30	4.30	5.04
		60/40	4.24	7.70
		50/50	4.62	10.28

ANOVA

Parameters	Sem ±	CD (5 %)	CV (%)
Method of spinning (A)	0.071	0.198*	12.349
Fibre content (B)	0.061	0.172*	
Blend ratio (C)	0.061	0.172*	
Method of spinning X Fibre content (A x B)	0.032	0.089*	
Fibre content X Blend ratio (A x C)	0.024	0.089*	
Method of spinning x Blend ratio (A x C)	0.285	0.798*	
Method of spinning X Fibre content X Blend ratio (A x B x C)	0.095	0.266*	

*Significant at 5 per cent level

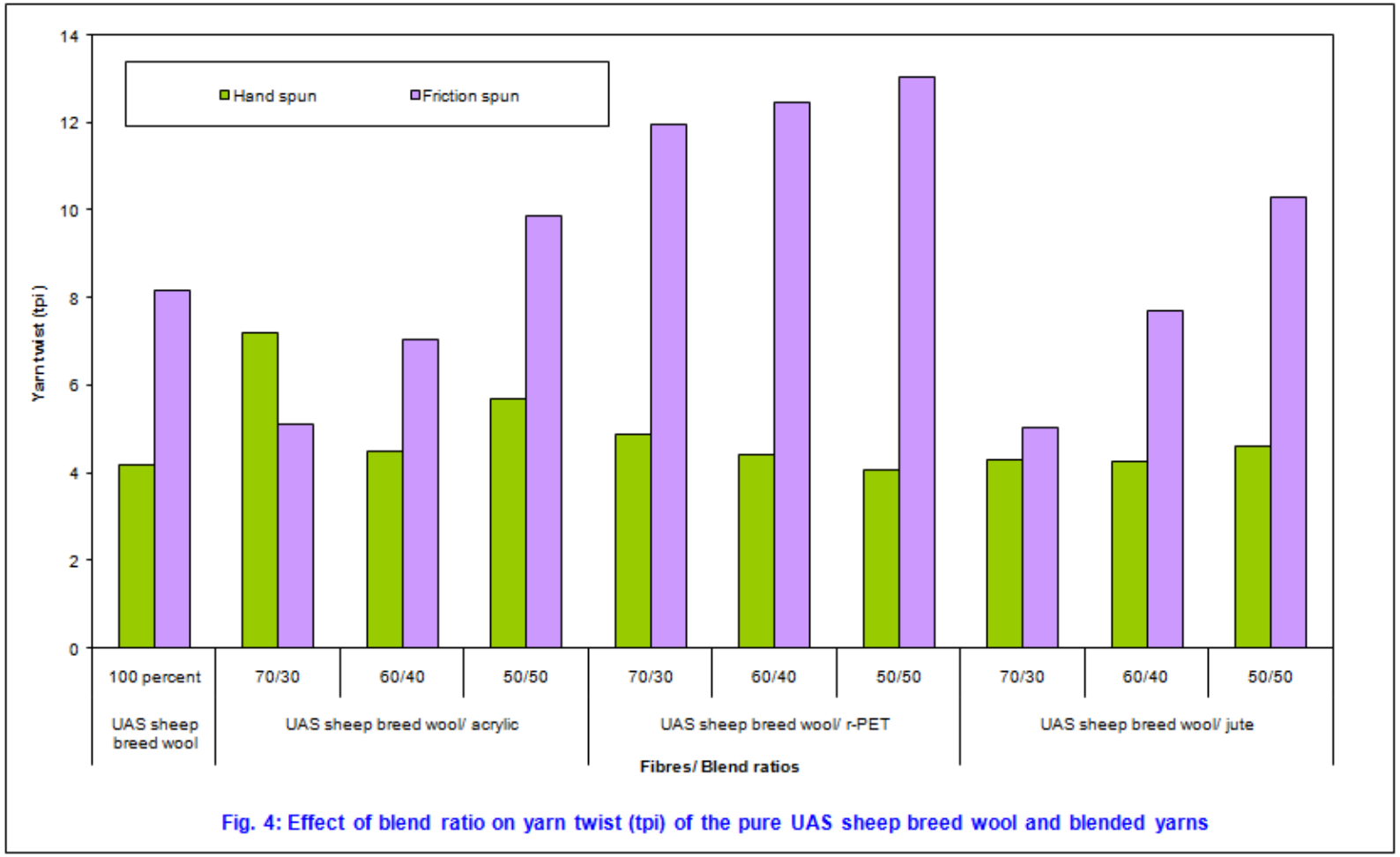


Fig. 4: Effect of blend ratio on yarn twist (tpi) of the pure UAS sheep breed wool and blended yarns

Fig. 4: Effect of blend ratio on yarn twist (tpi) of the pure UAS sheep breed wool and blended yarns

Table 5: Effect of blend ratio on single yarn strength (kgf) of the pure UAS sheep breed wool and blended yarns

Sl.No.	Fibres	Blend ratios	Single yarn strength (kgf)	
			Hand spun	Friction spun
1	UAS sheep breed wool	100 per cent	0.26	0.25
2	UAS sheep breed wool/ acrylic	70/30	0.52	0.22
		60/40	0.48	0.27
		50/50	0.44	0.55
3	UAS sheep breed wool/ r-PET	70/30	0.62	0.33
		60/40	0.55	0.39
		50/50	0.61	0.30
4	UAS sheep breed wool/ jute	70/30	0.26	0.28
		60/40	0.35	0.49
		50/50	0.23	0.40

ANOVA

Parameters	Sem ±	CD (5 %)	CV (%)
Method of spinning (A)	0.006	0.017*	18.623
Fibre content (B)	0.005	0.015*	
Blend ratio (C)	0.005	0.015*	
Method of spinning X Fibre content (A x B)	0.003	0.008*	
Fibre content X Blend ratio (A x C)	0.002	0.008*	
Method of spinning x Blend ratio (A x C)	0.024	0.068*	
Method of spinning X Fibre content X Blend ratio (A x B x C)	0.008	0.023*	

*Significant at 5 per cent level

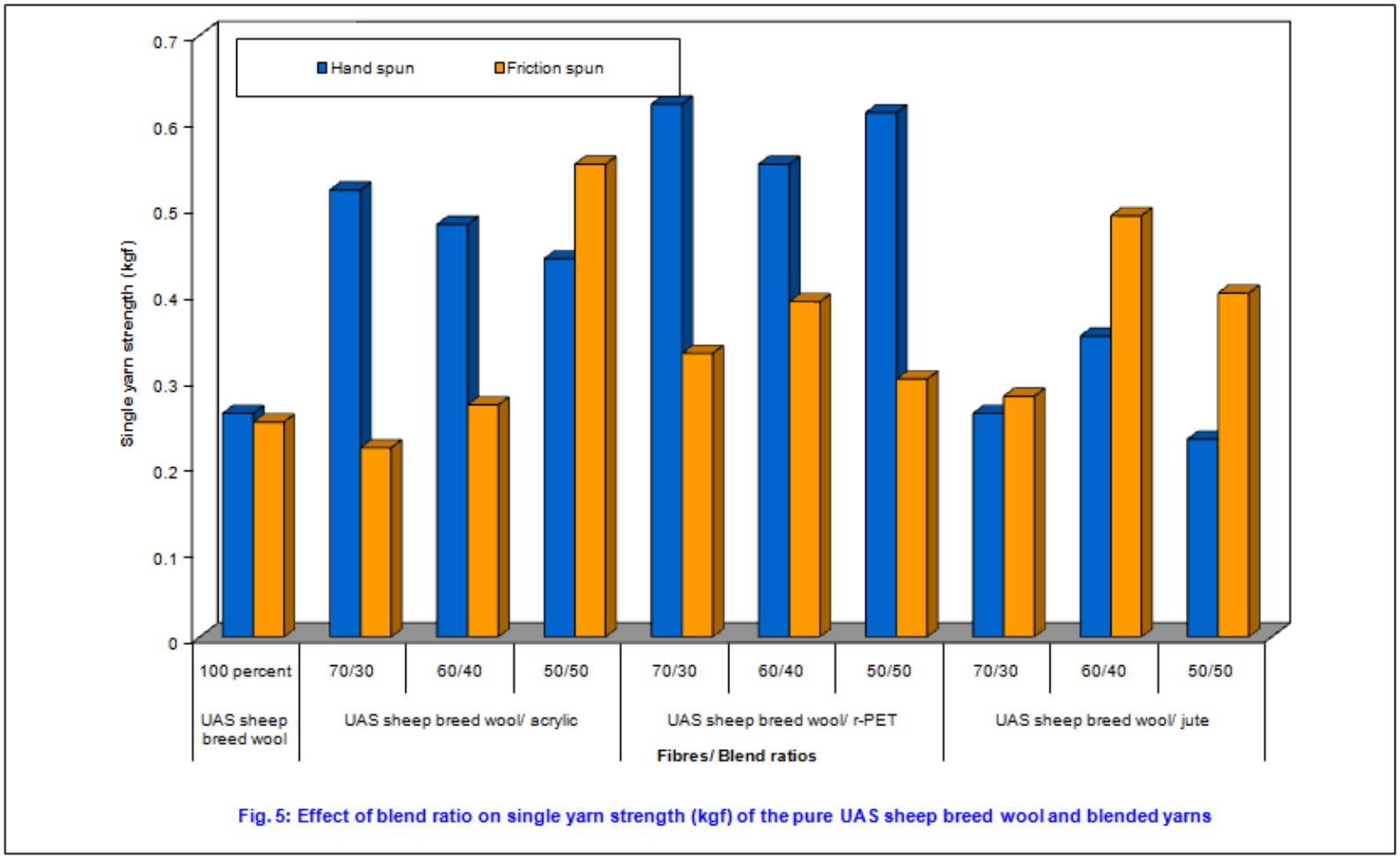


Fig. 5: Effect of blend ratio on single yarn strength (kgf) of the pure UAS sheep breed wool and blended yarns

Fig. 5: Effect of blend ratio on single yarn strength (kgf) of the pure UAS sheep breed wool and blended yarns

Hand spun and friction spun yarns of UAS sheep breed wool/ jute 60/40 blended yarns showed higher strength (0.35 and 0.49) followed by 70/30 (0.26 and 0.28) and 50/50 blended yarns (0.23 and 0.27).

4.2.4 Effect of blend ratio on yarn elongation (%) of the pure UAS sheep breed wool and blended yarns

Elongation is the increase in length of the specimen from its starting length expressed in percentage. The distance that a material will extend under a given force is proportional to its original length, therefore elongation is usually quoted as strain or percentage extension (Saville, 2004).

From the Table 6 and Fig. 6 it is clear that, irrespective of fibre content, blend ratio and spinning methods, yarn elongation was found to be more in friction spun blended yarns than the hand spun blends. Yarn elongation of UAS sheep breed wool blended yarns increased significantly than the pure UAS sheep breed wool yarns with respect to method of spinning (A), fibre content (B), blend ratios (C) and interaction of A x B, B x C, A x C and the combined interaction effect of A x B x C.

The hand spun pure UAS sheep breed wool yarn exhibited lower elongation percentage (3.75) than the UAS sheep breed wool/ acrylic and UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends, whereas higher than UAS sheep breed wool/ jute blended yarns. However, the friction spun pure UAS sheep breed wool (8.71) explored the least elongation than the other UAS sheep breed wool blended friction spun yarns.

Among the hand spun UAS sheep breed wool/ acrylic blends, the highest percentage of elongation was seen in the 60/40 blend ratio (6.30) followed by 70/30 blend ratio (6.24) and 50/50 (3.98) respectively. In the friction spun UAS sheep breed wool/ acrylic blended yarns, the elongation percentage increased with the increase of the acrylic fibre content in the blend ratio *i.e.,* 14.62 (50/50), 14.59 (60/40) and 13.08 (70/30) respectively.

Further in the hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends, the 60/40 blended yarn depicted greater elongation percentage (4.73) than the 70/30 (4.65) and 50/50 (4.59) yarns. However, increased recycled polyethylene terephthalate (r-PET) fibre in the blend ratio increased elongation percentage of the friction spun UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarns *i.e.,* 50/50 (9.92), 60/40 (9.74) and 70/30 (9.55) respectively.

The least elongation percentage was found in the hand spun UAS sheep breed wool/ jute (60/40) yarn (1.90) followed by the 50/50 (1.48) and 70/30 (1.04). In case of friction spun yarns, the UAS sheep breed wool/ jute (60/40) blended yarns registered higher percentage of elongation (18.84) followed by 70/30 (15.68) and 50/50 (11.62).

4.2.5 Effect of blend ratio on yarn evenness of the pure UAS sheep breed wool and blended yarns

Hand spun pure UAS sheep breed wool and blended yarns (Table 7a and Fig. 7)

Yarn evenness is defined as the variation in weight per unit length of the yarn or as the variation in its thickness (Saville, 2004). The yarn evenness is assessed in terms of thick places/ km (+ 50 %), thin places/ km (- 50 %), neps/ km (+ 200 %) and unevenness percentage ratio. The productant of all these factors gives total imperfections of the yarn. It was found to be a significant difference in unevenness percentage, number of thick, thin places and neps in the hand spun pure UAS sheep breed wool and blended yarns.

Table 6: Effect of blend ratio on yarn elongation (%) of the pure UAS sheep breed wool and blended yarns

Sl. No.	Fibres	Blend ratios	Yarn elongation (%)	
			Hand spun	Friction spun
1	UAS sheep breed wool	100 per cent	3.75	8.71
2	UAS sheep breed wool/ acrylic	70/30	6.24	13.08
		60/40	6.30	14.59
		50/50	3.98	14.62
3	UAS sheep breed wool/ r-PET	70/30	4.65	9.55
		60/40	4.73	9.74
		50/50	4.59	9.92
4	UAS sheep breed wool/ jute	70/30	1.04	15.68
		60/40	1.90	18.84
		50/50	1.48	11.62

ANOVA

Parameters	Sem ±	CD (5 %)	CV (%)
Method of spinning (A)	0.116	0.325*	17.014
Fibre content (B)	0.101	0.281*	
Blend ratio (C)	0.101	0.281*	
Method of spinning X Fibre content (A x B)	0.052	0.145*	
Fibre content X Blend ratio (A x C)	0.039	0.109*	
Method of spinning x Blend ratio (A x C)	0.470	1.309*	
Method of spinning X Fibre content X Blend ratio (A x B x C)	0.156	0.436*	

*Significant at 5 per cent level

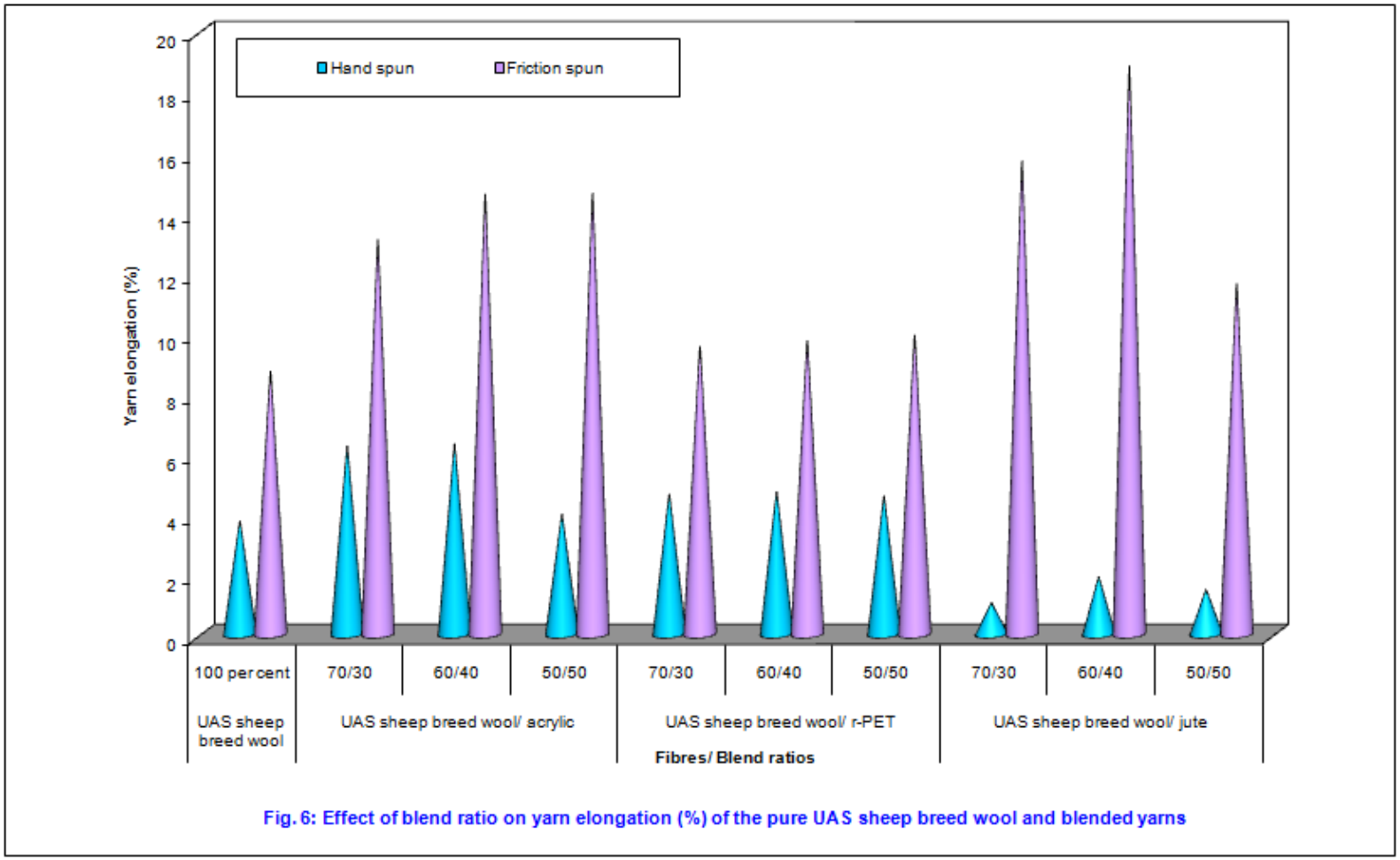


Fig. 6: Effect of blend ratio on yarn elongation (%) of the pure UAS sheep breed wool and blended yarns

Fig. 6: Effect of blend ratio on yarn elongation (%) of the pure UAS sheep breed wool and blended yarns

In general, the unevenness percentage, number of thick, thin places and neps of the hand spun UAS sheep breed wool and blended yarns significantly higher than the control samples.

- Unevenness percentage (U %)

The unevenness percentage (U %) gives an overall number for yarn irregularities. The pure UAS sheep breed wool yarn possessed relatively even yarn with unevenness percentage (25.60) compared to UAS sheep breed wool blended yarns. Among the yarn samples, the unevenness percentage was found to be highest in UAS sheep breed wool/ acrylic blended yarn, 39.30 per cent (60/40) followed by 35.20 per cent (70/30) and 27.60 per cent (50/50). In the UAS sheep breed wool/ acrylic blended yarns, 50/50 blend ratio had more evenness as compared to other blend ratios.

The control sample was found to be more even (25.60) and unevenness percentage was on par with UAS sheep breed wool/ acrylic blend. However in the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarns, the 50/50 blended yarn possessed higher unevenness percentage (36.70) than the 60/40 (31.80) and 70/30 (28.10). The results indicated that, the unevenness percentage increased with the increase of recycled polyethylene terephthalate (r-PET) content in the blend ratio.

Further, less unevenness percentage was seen in the UAS sheep breed wool/ jute blends compared to UAS sheep breed wool/ acrylic and UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends which showed that UAS sheep breed wool/ jute blends are more even. Among the UAS sheep breed wool/ jute blends, the 60/40 blend ratio possessed maximum unevenness percentage followed by UAS sheep breed wool/ jute 50/50 (25.0) and UAS sheep breed wool/ jute 70/30 (24.80).

The trend of unevenness percentage among the hand spun yarns noticed that, the recycled polyethylene terephthalate (r-PET) content increases in the yarn with increase in unevenness percentage and yarn becomes more uneven.

- Thick places/ km (+ 50 %)

A thick place is the region where the cross-sectional size bigger by 50 % of the average size (Ratnam *et al.* 1994).

Table 7a depicts the thick places/ km (+ 50 %) of the hand spun pure UAS sheep breed wool and blended yarns. The hand spun pure UAS sheep breed wool yarn exhibited least number of thick places (1854.30) indicated more even the yarn. In general among all the blends, the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends exhibited higher number of thick places than UAS sheep breed wool/ acrylic and UAS sheep breed wool/ jute blends. In the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends, the more number of thick places were observed in the 50/50 (4975.30) followed by 60/40 (4755.70) and 70/30 (2693.70). As the percentage of recycled polyethylene terephthalate (r-PET) increased in the blend ratio, the number of thick places also increased.

In the UAS sheep breed wool/ acrylic blends, the 70/30 (4593.30) showed maximum number of thick places than 60/40 (4314.70) and 50/50 (2835.70). A trend of decrease in number of thick places with the increase in acrylic proportion in the blend was noticed.

Further the less number of thick places were found in the UAS sheep breed wool/ jute blends compared to UAS sheep breed wool/ acrylic and UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends. The more number of thick places were seen in the UAS sheep breed wool/ jute 60/40 (2013.70) followed by 70/30 (1915.70) and UAS sheep breed wool/ jute 50/50 (952.00).

- Thin places/ km (- 50 %)

A thin place is the region where the cross-sectional size smaller by 50 % of the average size (Ratnam *et al.* 1994).

Thin places (- 50 %) of hand spun pure UAS sheep breed wool and its blends. The hand spun pure UAS sheep breed wool performed very less number of thin places (2262.30) as compared to its blended yarns. The highest numbers of thin places were found in the UAS sheep breed wool/ acrylic blends. The UAS sheep breed wool/ acrylic yarn (60/40) exhibited maximum number of thin places (10369.70) compared to 70/30 (6697.70) and 50/50 (4835.30).

However in the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends, the 50/50 blend ratio possessed more number of thin places (10369.70) compared to 60/40 (5757.70) and 70/30 (4524.30). It was perceived that, the number of thin places increased with the increase of recycled polyethylene terephthalate (r-PET) proportion in the blend ratio.

Further the UAS sheep breed wool/ jute blends illustrated minimum number of thin places than UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) and UAS sheep breed wool/ acrylic blends. In the UAS sheep breed wool/ jute blends, the higher number of thin places were seen in the 60/40 (3173.30) followed by 70/30 (2677.70) and 50/50 (2415.30).

- Neps/ km (+ 200 %)

Neps are small knot like aggregates of entangled fibres. High incidence of neps is responsible for poor appearance and appeal characteristics of yarns and fabrics, formation of spotty and streaky materials during dyeing and printing, end breaks during winding, warping, weaving and knitting, and lower price realization (Ratnam *et al.* 1994).

In general, the hand spun pure UAS sheep breed wool yarn possessed less number of neps (195.10) than the other blends.

Higher numbers of neps were noticed in the UAS sheep breed wool/ acrylic blends. Among this group, 60/40 blended yarn possessed greater number of neps (3655.30) followed by 70/30 (1928.70) and 50/50 (571.10).

However in the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends, the 50/50 blend ratio showed more number of neps (1580.00) compared to 60/40 (810.00) and 70/30 (451.10).

Whereas, less number of neps were obtained in the UAS sheep breed wool/ jute blends. The 50/50 blend ratio showed higher number of neps (309.80) followed by 70/30 (202.20) and 60/40 (164.40).

- Total imperfections

The total imperfections are the resultant of the evenness properties. These are the larger short-term deviations from the mean thickness and they comprise thin places, thick places and neps (Saville, 2004).

Among the hand spun UAS sheep breed wool blends, total imperfection rate was found to be exorbitantly high in the UAS sheep breed wool/ acrylic blends *i.e.,* 60/40 (18339.70), 70/30 (13221.70) and 50/50 (8242.10). The results indicated that yarn becomes more uneven than the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) and UAS sheep breed wool/ jute blends. Further in the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarns, as the wool percentage decreases and recycled polyethylene terephthalate (r-PET) proportion increases total imperfections rate were also more *i.e.,* 50/50 (13850.70), 60/40 (11323.30) and 70/30 (7669.10) respectively.

However, UAS sheep breed wool/ jute blends had lesser total imperfections and resultant yarn was more even as the jute content increased in the blend *i.e.,* 60/40 (5351.40), 70/30 (4795.50) and 50/50 (3677.10). The total imperfections of the control sample (4311.80) were found to be on par with UAS sheep breed wool/ jute blends and highlights more even yarn.

Friction spun pure UAS sheep breed wool and blended yarns

A significant increase of unevenness percentage, number of thick, thin places and neps in the friction spun UAS sheep breed wool blended yarns.

- Unevenness percentage (U %)

Evenness results of the friction spun UAS sheep breed wool and blended yarns were given in Table 7b and Fig. 8. The results depicted that UAS sheep breed wool/ acrylic blended yarns have high unevenness percentage than UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) and UAS sheep breed wool/ jute blends. Among the UAS sheep breed wool/ acrylic blended yarns, the highest value of unevenness percentage belongs to 70/30 (28.20) followed by 60/40 (25.40) and 50/50 (23.60). The UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) possessed greater unevenness percentage (24.40) compared to 60/40 (23.90) and 50/50 (19.70) indicated yarn was more uneven.

However in the UAS sheep breed wool/ jute blends, the 70/30 blend ratio (21.50) attained higher unevenness percentage than the 60/40 (21.20) and 50/50 (13.30) resulting that the UAS sheep breed wool/ jute blended yarns were more even with less unevenness percentage.

The friction spun pure UAS sheep breed wool sample possessed lesser unevenness percentage (24.50) compared to UAS sheep breed wool/ acrylic blends whereas the unevenness percentage of pure UAS sheep breed wool was on par with UAS sheep breed wool/ jute indicating more even yarn.

- Thick places/ km (+ 50 %)

Thick places in the yarn appeared due to presence of large amount of trash, low micronaire with high level of immaturity, excessive fibre entanglements leads to formation of thick places in the yarn. Table 7b highlighted the thick places/ km (+ 50 %) of the friction spun UAS sheep breed wool and blended yarns. Irrespective of fibre content and blend ratio, the thick places in the yarn were found to be more in UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends (70/30-3660.00) followed by UAS sheep breed wool/ acrylic (70/30-3437.00), control sample (3193.00) and UAS sheep breed wool/ acrylic blends (60/40- 2744.30).

Table 7a: Effect of blend ratio on yarn evenness of the hand spun pure UAS sheep breed wool and blended yarns

Sl. No.	Fibres	Blend ratios	Yarn evenness				
			U %	Thick places	Thin places	Neps 200/ km	Total imperfections
1	UAS sheep breed wool	100	25.60	1854.30	2262.30	195.10	4311.80
2	UAS sheep breed wool/ acrylic	70/30	35.20	4595.30	6697.70	1928.70	13221.70
		60/40	39.30	4314.70	10369.70	3655.30	18339.70
		50/50	27.60	2835.70	4835.30	571.10	8242.10
3	UAS sheep breed wool/ r-PET	70/30	28.10	2693.70	4524.30	451.10	7669.10
		60/40	31.80	4755.70	5757.70	810.00	11323.30
		50/50	36.70	4975.30	7300.30	1580.00	13855.70
4	UAS sheep breed wool/ jute	70/30	24.80	1915.70	2677.70	202.20	4795.50
		60/40	25.80	2013.70	3173.30	164.40	5351.40
		50/50	25.00	952.00	2415.30	309.80	3677.10

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun UAS sheep breed wool and blended yarns	**U %**	0.677	0.385*	3.912
	Thick places	213.584	121.257*	11.970
	Thin places	249.229	141.494*	8.631
	Neps 200/ km	170.352	96.713*	29.901
	Total imperfections	573.601	347.845*	11.082

*Significant at 5 per cent level

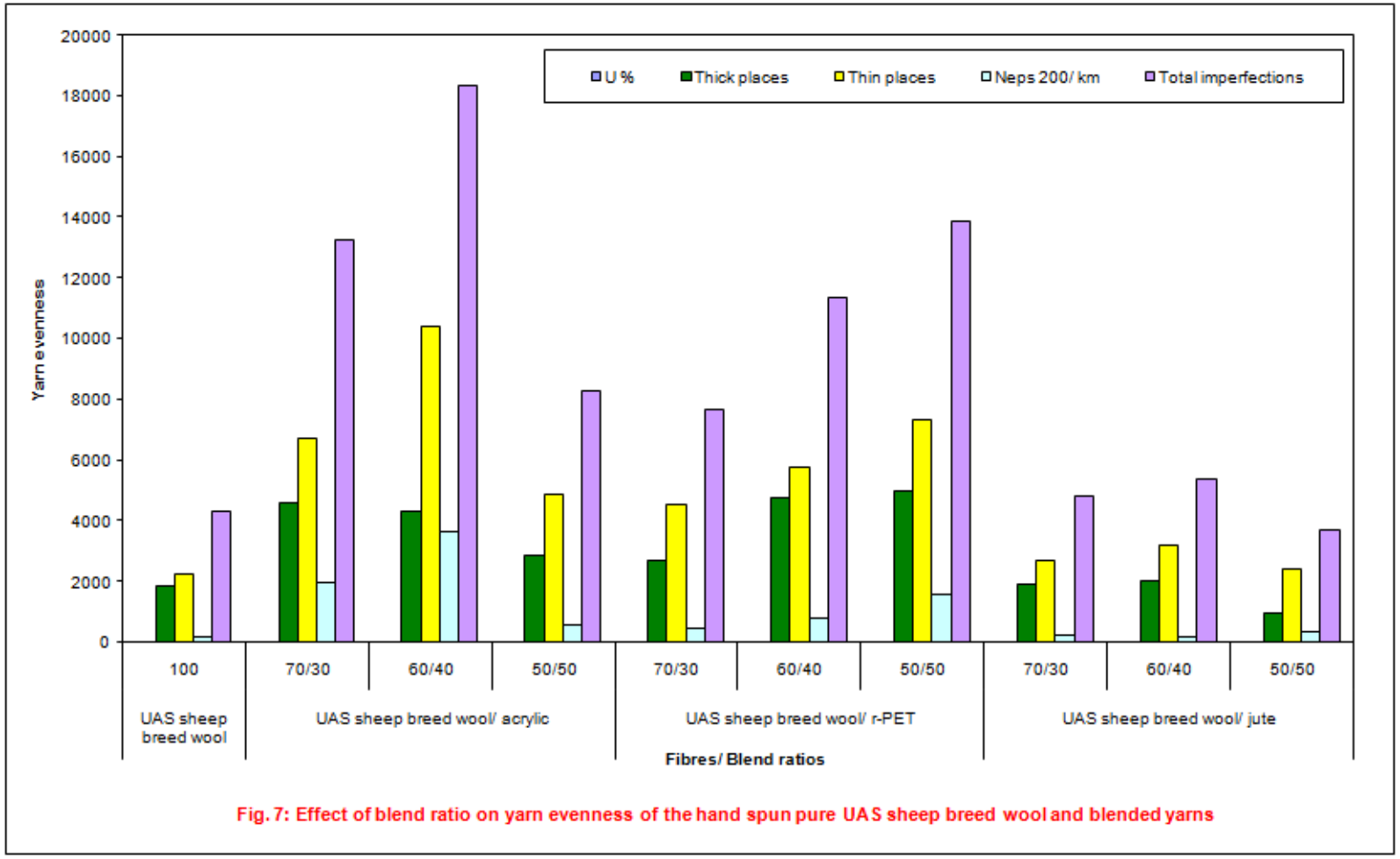


Fig. 7: Effect of blend ratio on yarn evenness of the hand spun pure UAS sheep breed wool and blended yarns

With respect to fibre content and blend ratio, the 70/30 blend ratio of UAS sheep breed wool/ recycled polyethylene terephthalate (3660.00) showed maximum number of thick places followed by 60/40 (1080.70) and 50/50 (900.30) respectively. The thick places reduced with the increase of recycled polyethylene terephthalate (r-PET) content in the blend ratio.

However in the UAS sheep breed wool/ acrylic blends, the higher number of thick places were seen in the 70/30 blends (3437.00) followed by 60/40 (2744.30) and 50/50 (2431.30). A trend of decrease in number of thick places with the increase in acrylic proportion in the blend was observed.

In the UAS sheep breed wool/ jute blends the 60/40 blended yarns possessed more number of thick places (2060.00) than 70/30 (1639.00) and 50/50 (173.30).

From the above results it can be stated that, with the increase of recycled polyethylene terephthalate, acrylic and jute fibres in the blend mixture, the decrease in number of thick places.

- Thin places/ km (- 50 %)

The table 7b indicated the thin places/ km (- 50 %) of the friction spun pure UAS sheep breed wool and blended yarns. The pure UAS sheep breed wool yarn attained comparatively more number of thin places (4526.70) than the other blends. The UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarn of 60/40 (4617.70) and 70/30 (4505.00) showed higher thin places than the 50/50 (3723.30). Among the UAS sheep breed wool/ acrylic blended yarns, 70/30 blend ratio achieved greater number of thin places (4385.70) followed by 60/40 (4008.70) and 50/50 (2763.30). However more evenness was resulted in the UAS sheep breed wool/ jute blends. The UAS sheep breed wool/ jute blended yarn of 60/40 (2716.00) exhibited more number of thin places compared to 70/30 (1437.70) and 50/50 (275.30).

- Neps/ km (+ 200 %)

Neps/ km (+ 200 %) of the friction spun pure UAS sheep breed wool and blended yarns shown in the Table 7b. Among the friction spun pure UAS sheep breed wool and wool blends, more number of neps were formed in the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blended yarns of ratio 70/30 (8480.00) than 60/40 (8132.00) and 50/50 (6327.30). Whereas the UAS sheep breed wool/ jute blends of 70/30 ratio possessed higher number of neps (3044.70) than the 50/50 (455.00) and 60/40 blend ratio (452.70). In case of UAS sheep breed wool/ acrylic blends, the 70/30 blended yarn exhibited maximum neps (2674.70) followed by the 50/50 (2674.30) and 60/40 (2076.00).

- Total imperfections

Table 7b implies the total imperfections of the friction spun pure UAS sheep breed wool and blended yarns. The total imperfections of the control sample (14926.00) were found to be on par with UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends and highlights uneven yarn. In the friction spun pure and blended yarns, the more imperfections were seen in the UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) blends. As the percentage of recycled polyethylene terephthalate (r-PET) increases in the blend, the yarns become more even (70/30 - 16645.00, 60/40 - 13830.30 and 50/50 - 10951.00).

Table 7b: Effect of blend ratio on yarn evenness of the friction spun pure UAS sheep breed wool and blended yarns

Sl. No.	Fibres	Blend ratios	Yarn evenness				
			U %	Thick places	Thin places	Neps 200/ km	Total imperfections
1	UAS sheep breed wool	100	24.50	3193.00	4526.70	7206.30	14926.00
2	UAS sheep breed wool/ acrylic	70/30	28.20	3437.00	4385.70	2674.70	10497.30
		60/40	25.40	2744.30	4008.70	2076.00	8829.00
		50/50	23.60	2431.30	2763.30	2674.30	7869.00
3	UAS sheep breed wool/ r-PET	70/30	24.40	3660.00	4505.00	8480.00	16645.00
		60/40	23.90	1080.70	4617.70	8132.00	13830.30
		50/50	19.70	900.30	3723.30	6327.30	10951.00
4	UAS sheep breed wool/ jute	70/30	21.50	1639.00	1437.70	3044.70	6121.30
		60/40	21.20	2060.30	2716.00	452.70	5229.00
		50/50	13.30	173.30	275.30	455.00	903.70

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Friction spun UAS sheep breed wool and blended yarns	**U %**	0.327	0.185*	2.512
	Thick places	21.503	12.207*	1.747
	Thin places	70.358	39.944*	3.697
	Neps 200/ km	14.230	8.079*	0.593
	Total imperfections	69.147	41.932*	1.254

*Significant at 5 per cent level

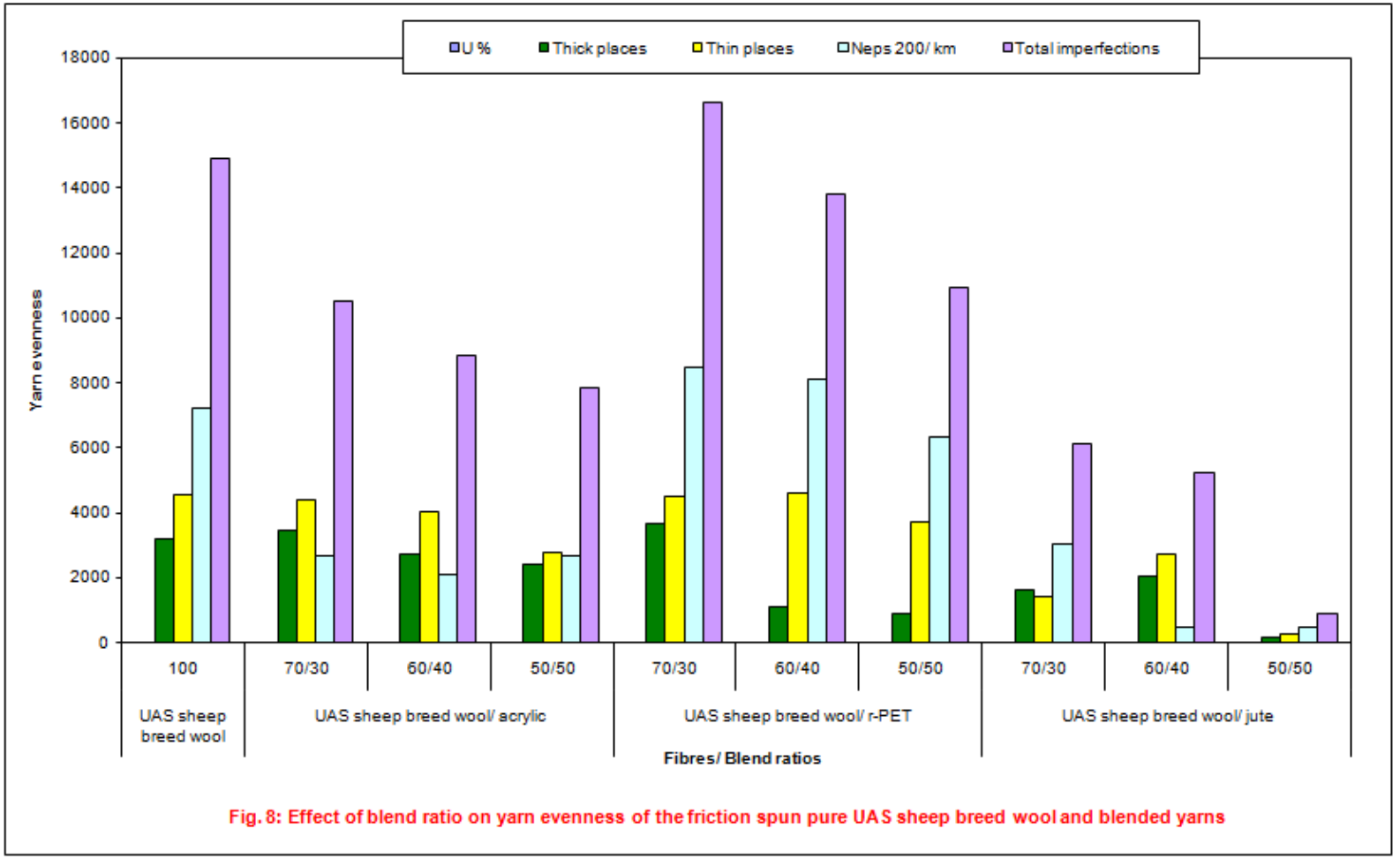


Fig. 8: Effect of blend ratio on yarn evenness of the friction spun pure UAS sheep breed wool and blended yarns

Further, the UAS sheep breed wool/ acrylic blends had relatively lesser total imperfections and resultant yarn was uneven *i.e.,* 10497.30 (70/30), 8829.00 (60/40) and 7869.00 (50/50). A blended yarn becomes even, as the acrylic content increased in the blend.

However, the UAS sheep breed wool/ jute blends exhibited more even yarn with less number of imperfections and trend of decrease in imperfections as the jute fibre increased in the blends *i.e.,* 70/30 (6121.30), 60/40 (5229.00) and 50/50 (903.70) respectively.

4.3 Development of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The technique of weaving is fundamentally means that interlacements of two sets of yarns *i.e.,* warp and weft yarns at right angle to each other, accords to a pre-arranged design by means of loom. In the present study, four different types of union fabrics were woven on hand loom using 2/20s cotton as warp with two varieties of hand spun pure UAS sheep breed wool (control) and UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) and friction spun pure UAS sheep breed wool (control) and UAS sheep breed wool/ jute (60/40) yarns as weft. Two control yarns *i.e.,* pure UAS sheep breed wool of hand spun and friction spun were used with 2/20s cotton. Among the hand spun and friction spun blended yarns from each spinning method *i.e.,* hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) and friction spun UAS sheep breed wool/ jute (60/40) respectively were selected for the fabric construction based on the yarn physical and evenness properties.

The production of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics involved various process like pre-loom, loom and post-loom processes which are dealt separately in this chapter.

Weaving cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Cotton x hand spun pure UAS sheep breed wool (control), cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) blended, cotton x pure UAS sheep breed wool friction spun and cotton x UAS sheep breed wool/ jute (60/40) blend union fabrics were woven with 2/2 twill weave on hand loom at Karnataka Handloom Development Center (KHDC), Narasapura weaving cluster at Gadag.

i) Pre-loom process

The union fabrics underwent various pre loom processes like warping, beaming and pirn winding

a) Warping

The sectional warping was the technique adopted for warping. In this technique, the warp threads *i.e.,* 2/20s cotton spools are placed on the spool rack or creel machine. The threads are drawn from the spool rack under uniform tension to make the required width of cloth.

b) Beaming

The process of winding the previously prepared warp in the form of sheet under control tension on to a beam is known as beaming. The beam is often provided with disc or flanges on both the ends to maintain the required width of warp to keep the selvedge ends in control.

Table 8: Loom particulars of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Particulars	Union fabrics			
		Hand spun		Friction spun	
		Pure UAS sheep breed wool (control)	UAS sheep breed wool/ r-PET (70/30)	Pure wool (control)	UAS sheep breed wool/ jute (60/40)
1	Type of loom	Hand loom	Hand loom	Hand loom	Hand loom
2	Reed count	60s	60s	60s	60s
3	Reed width	64”	64”	64”	64”
4	Cloth width	63”	63”	63”	63”
5	Denting order	2 threads/ dent	2 threads/ dent	2 threads/ dent	2 threads/ dent

c) Pirn winding

The pure UAS sheep breed wool and wool blended hand and friction spun yarns were wound onto pirns with help of manually operated pirn winder. Pirn winder is an important adjunct to the loom since successful weaving depends on good winding (Plate 18).

ii) Loom process

a) Loom particulars and weaving

All the union fabrics were woven on hand loom with reed count of 60s, reed width of 64 inches, cloth width of 63 inches, denting order of 2 threads/ dent with 2/2 twill weave (Table 8) (Plate 19 and 20).

b) Cutting and doffing

After weaving, a known length of material, an extra length of approximately an inch was woven and separated from the cloth beam with knife. This helped to prevent the slippage of yarns through the dents.

iii) Post-loom process

The woven fabrics were examined for flaws, then folded and further used for mechanical and functional testing (Plate 21 - 25).

4.4 Assessment of mechanical properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The developed union fabrics were subjected to mechanical properties *viz.,* cloth count, cloth thickness, cloth GSM, bending length and cloth crease recovery.

4.4.1 Cloth count (Numerical expression) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Cloth count of the woven textile material is the number of ends and picks per unit area which is influenced by the yarn count and compactness of the weave. It is also expressed as cloth density *i.e.,* alignment of single, ply, cable and fancy yarns which not only influence the yarn count but also the mechanical and functional properties of the ultimate cloth.

Irrespective of method of spinning, blend ratio and fibre content, the warp density was relatively greater (60) than the weft (16-23). In general, friction spun union fabrics possessed better cloth density than the hand spun union fabrics. Further, the statistical results showed that the cloth density of blended union fabrics *i.e.,* cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) and cotton x friction spun pure UAS sheep breed wool/ jute (60/40) were significantly higher than their respective control fabrics.

The cloth count of hand spun union fabrics *i.e.,* control and cotton x blended fabrics (70/30 UAS sheep breed wool/ recycled polyethylene terephthalate) explored relatively similar thread density in both warp way and weft way (59 x 16 and 60 x 17) respectively.

In case of friction spun union fabrics, the cotton x pure UAS sheep breed wool union fabrics registered slightly lower thread density (58 x 22) than cotton x UAS sheep breed wool/ jute (60/40) union fabrics (60 x 23).



Plate 18. Pirn winding of the pure and UAS blended yarns



Plate 19. Weaving of the UAS sheep breed wool blended union fabrics



Plate 20. Close up weaving UAS sheep breed wool blended union fabrics



Plate 21. Examination for fabric flaws



Plate 22. Cotton x hand spun pure UAS sheep breed wool union fabric



Plate 23. Cotton x hand spun UAS sheep breed wool/ r-PET (70/30) union fabric



Plate 24. Cotton x friction spun pure UAS sheep breed wool union fabric



Plate 25. Cotton x friction spun UAS sheep breed wool / jute (60/40) union fabric

Table 9: Cloth count (Ne) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Direction	
			Warp way	Weft way
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	59	16
		Cotton x UAS sheep breed wool/ r-PET (70/30)	60	17
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	58	22
		Cotton x UAS sheep breed wool/ jute (60/40)	60	23

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Warp	0.424	0.040*	2.247
	Weft	0.249	0.023*	4.723
Friction spun union fabrics	Warp	0.570	0.054*	3.043
	Weft	0.302	0.028*	4.280

*Significant at 5 per cent level

4.4.2 Cloth weight (GSM) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Fabric mass per unit area is expressed either as grams per square meter or grams per linear meter. The type of fibre, yarn density, weave type and finish applied are some factors contribute to the fabric weight.

Of the hand spun union fabrics, the control *i.e.,* cotton x pure UAS sheep breed wool showed higher cloth weight (428) compared to the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric (388). It holds well in a woven cloth that, many times the warp and weft percentage is not equal which is evident from Table 10. The warp per cent was greater in cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric (43.52) than control fabric (41.04) and the weft percentage was higher (57.67) in the control *i.e.,* cotton x pure UAS sheep breed wool compared to cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric (55.25).

Further, the data in the Table 10 depicts the cloth weight of the friction spun union fabrics. The cotton x UAS sheep breed wool/ jute (60/40) fabric (292) was comparatively heavier than the control *i.e.,* cotton x pure UAS sheep breed wool union fabric (288). However, the warp percentage was high in the cotton x UAS sheep breed wool/ jute (60/40) fabric (57.52) when compared to control sample *i.e.,* cotton x pure UAS sheep breed wool union fabric (56.88), whereas weft per cent was more in the control sample *i.e.,* cotton x pure UAS sheep breed wool union fabric (45.56) than the cotton x UAS sheep breed wool/ jute fabric (42.17) respectively.

In general irrespective of spinning methods, cloth weight of the cotton x hand spun pure UAS sheep breed wool union fabric was found to be significantly heavier than the other three union fabrics.

Further, the statistical results showed that the cloth weight of cotton x hand spun pure UAS sheep breed wool fabric was significantly higher than the other union fabrics.

4.4.3 Cloth thickness (mm) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The thickness of a fabric is one of its basic properties giving information on its warmthness, heaviness or stiffness in use. When a fabric is compressed the space between the fibres decreased until they eventually come in contact with one another (Saville, 2004). Fabric thickness depends upon the fibre content, yarn count, yarn type and weave density of the fabric which effects the fabric properties *viz.,* cloth stiffness, resiliency, crease recovery angle, drapability, abrasion resistance, thermal insulation and fabric geometry.

Cotton x hand spun pure UAS sheep breed wool union fabric was thicker (2.64) than the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric (2.16).

Among the friction spun union fabrics, the thickness was slightly higher in case of cotton x UAS sheep breed wool/ jute (60/40) union fabric (1.68) when compared to cotton x pure UAS sheep breed wool control sample (1.65).

Irrespective of fibre content, blend ratio and method of spinning, the cotton x hand spun pure UAS sheep breed wool union fabric was significantly thicker than the other union fabrics (Table 11).

Table 10: Cloth weight (GSM) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Total weight (g/sq. mt)	Per cent warp	Per cent weft
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	428	41.04	57.67
		Cotton x UAS sheep breed wool/ r-PET (70/30)	388	43.52	55.25
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	288	56.88	42.56
		Cotton x UAS sheep breed wool/ jute (60/40)	292	57.52	42.17

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Total weight (g/sq. mt)	10.643	3.105*	5.845
	Per cent warp	0.814	0.238*	4.307
	Per cent weft	0.719	0.210*	2.848
Friction spun union fabrics	Total weight (g/sq. mt)	3.731	1.088*	2.873
	Per cent warp	0.599	0.175*	2.357
	Per cent weft	0.644	0.188*	3.387

*Significant at 5 per cent level

4.4.4 Cloth crease recovery angle (degree) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Crease is an intentional folds incorporated in the fabric to enhance the aesthetic appeal. Creasing of a fabric during wear is not a change in appearance that is generally desired. The ability of a fabric to resist creasing is dependent on type of fibre used in the construction. Some fibres such as wool and silk have a good resistance to creasing whereas cellulosic materials such as cotton, viscose and linen have a very poor resistance to creasing (Saville, 2004).

In general, weft way crease recovery of union fabrics was found to be higher than the warp way crease recovery (Table 12).

Among the hand spun union fabrics, the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric showed higher cloth recovery (108.5) than the cotton x pure UAS sheep breed wool union fabric (73.62).

Whereas, in the friction spun union fabrics it was found that the cotton x UAS sheep breed wool/ jute (60/40) obtained greater crease recovery in weft way (103.80) and warp way (77.40) when compared to cotton x pure UAS sheep breed wool (76.00 and 95.00) union fabrics. However, slightly higher cloth recovery (89.61) was noticed in the cotton x pure UAS sheep breed wool fabric than the cotton x UAS sheep breed wool/ jute sample (87.00).

Generally, weft-way recovery was found to be higher than warp-way in all the four union fabrics. And more crease recovery curvature was seen in the hand spun cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) sample (108.50) than the other three union fabrics.

However, the crease recovery in cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric was significantly greater than the other union fabrics.

4.4.5 Cloth stiffness (cm) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Stiffness is one of the most widely used parameters to judge bending rigidity of a fabric by allowing a narrow strip of the fabric to bend to a fixed angle under its own weight. The length of the fabric required to bend on its own weight is measured and is known as the bending length. The higher the bending length, the stiffer is the fabric and vice versa.

The Table 13 inferred the stiffness of the hand spun and friction spun union fabrics. In the hand spun union fabrics, the cotton x pure UAS sheep breed wool union fabric possessed higher bending length in both directions *i.e.,* warp-way (1.77) and weft-way (2.12) compared to cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric *i.e.,* warp way (1.54) and weft way (1.59) respectively.

Further, in the friction spun union fabrics, the cotton x UAS sheep breed wool/ jute (60/40) fabric showed higher bending length in both warp (1.30) and weft way (1.33) than the cotton x pure UAS sheep breed wool fabric union fabric *i.e.,* warp way (1.23) and weft way (1.24) respectively.

The bending length of hand spun union fabrics was significantly higher than the friction spun union fabrics.

Table 11: Cloth thickness (mm) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Cloth thickness (mm)
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	2.64
		Cotton x UAS sheep breed wool/ r-PET (70/30)	2.16
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	1.65
		Cotton x UAS sheep breed wool/ jute (60/40)	1.68

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Cloth thickness	0.011	0.0010*	1.44754
Friction spun union fabrics		0.01238	0.0012*	2.35607

*Significant at 5 per cent level

Table 12: Cloth crease recovery (degree) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Direction		Cloth recovery
			Warp way	Weft way	
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	55.00	98.80	73.62
		Cotton x UAS sheep breed wool/ r-PET (70/30)	85.60	137.00	108.5
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	77.40	103.80	89.61
		Cotton x UAS sheep breed wool/ jute (60/40)	76.00	95.00	87.00

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Warp	2.383	0.695*	7.581
	Weft	1.822	0.531*	3.456
	Cloth recovery	1.703	0.497*	4.188
Friction spun union fabrics	Warp	1.442	0.421*	4.205
	Weft	2.369	0.244*	7.573
	Cloth recovery	1.301	0.134*	4.715

*Significant at 5 per cent level

Table 13: Cloth stiffness (cm) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Bending length (cm)	
			Warp way	Weft way
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	1.77	2.12
		Cotton x UAS sheep breed wool/ r-PET (70/30)	1.54	1.59
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	1.23	1.24
		Cotton x UAS sheep breed wool/ jute (60/40)	1.30	1.33

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Warp	0.021	0.003*	4.053
	Weft	0.026	0.002*	4.485
Friction spun union fabrics	Warp	0.020	0.002*	5.071
	Weft	0.017	0.002*	4.120

*Significant at 5 per cent level

4.5 Assessment of functional properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The developed union fabrics were subjected to functional properties *viz.,* cloth tensile strength and elongation percentage, cloth drapability, cloth abrasion resistance, cloth pilling and thermal insulation respectively.

4.5.1 Cloth tensile strength (kgf) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The tensile strength is the fundamental ability of the fabric to resist strain or rupture induced by external force. The strength of the individual fabric depends on its inherent properties *viz.,* fibre content, yarn type, yarn linear density, cloth density, GSM and thickness.

In general, the warp way tensile strength was significantly greater than the weft way in all the test samples (Table 14).

Cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric possessed greater tensile strength than the other union fabrics. Among the hand spun union fabrics, highest tensile strength was obtained in cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric in warp and weft way (50.20 and 23.88) than the control sample (48.32 and 13.18).

However, in the friction spun union fabrics, the cotton x UAS sheep breed wool/ jute (60/40) fabric showed higher tensile strength both warp and weft way (64.44 and 22.22) when compared to the control sample (53.52 and 11.98).

It was observed from the Table 14 that, in all the test samples warp way tensile strength was found to be greater. Among the four union fabrics, the cotton x friction spun UAS sheep breed wool/ jute (60/40) sample showed greater tensile strength in warp way (64.44) and weft way (22.22) than the rest of the samples.

Influence of yarn count and cloth count on the cloth tensile strength of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Table 14a depicts the influence of yarn count and cloth count on the cloth tensile strength of test samples. In case of cotton x hand spun pure UAS sheep breed wool union fabric, the yarn count was significantly influenced the warp way cloth tensile strength with R^2 value of 63 per cent. But the relation was negative *i.e.,* increase in yarn count resulted into decrease in tensile strength, which means coarser the yarn, higher the strength. On the other hand, yarn count and cloth count did not influence the cloth tensile strength of cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (r-PET) and blended union fabrics.

4.5.2 Cloth elongation (%) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

There was a significant difference in cloth elongation of the hand spun and friction spun union fabrics. Warp way elongation was significantly higher compared to weft way in all the test samples (Table 15).

Table 14: Cloth tensile strength (kgf) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Cloth tensile strength (kgf)	
			Warp way	Weft way
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	48.32	13.18
		Cotton x UAS sheep breed wool/ r-PET (70/30)	50.20	23.88
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	53.52	11.98
		Cotton x UAS sheep breed wool/ jute (60/40)	64.44	22.22

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Warp	0.961	0.280*	4.361
	Weft	0.318	0.093*	3.842
Friction spun union fabrics	Warp	0.912	0.266*	3.458
	Weft	0.221	0.065*	2.891

*Significant at 5 per cent level

In the hand spun union fabrics, the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric exhibited higher elongation percentage in warp way (19.02) than control sample (warp-18.52). Whereas in weft way, the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate fabric exhibited least elongation percentage (8.30) than the control sample (10.07).

Further, in the friction spun union fabrics, the elongation percentage was significantly greater in cotton x UAS sheep breed wool/ jute (60/40) union fabric in warp and weft way (17.94 and 18.75) compared to cotton x pure UAS sheep breed wool *i.e.,* warp way (15.80) and weft way (13.51) respectively.

Influence of yarn count and cloth count on the cloth elongation of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

It was found that, in the warp direction of cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric, the yarn count significantly influenced the cloth elongation with negative relation *i.e.,* increase in yarn count resulted into decrease in tensile strength which means finer the yarn, lower the elongation. In case of cotton x hand spun pure UAS sheep breed wool union fabric and cotton x friction spun pure UAS sheep breed wool union fabrics. The R^2 effect was greater (69 %) in cotton x hand spun pure UAS sheep breed wool and cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabrics (Table 15a).

4.5.3 Cloth drapability (nodes) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Drape, one of the most important properties of fabric, has played significant role in providing graceful aesthetic effects in garments. Drape is one of the subjective performance characteristic of fabric that contributes to its aesthetic appeal. A fabric is said to possess good drapability when configuration is pleasant to the eye. Drapability is a result of the interaction between warp-way and weft-way characteristics. The drape coefficient of fabric has direct relation with firmness of weave and cloth sett. The objective evaluation of cloth drapability is expressed in terms of drape co-efficient (%), however the drapability of some fabric may be evaluated subjectively and expressed in terms of number of nodes formed when draped.

From the Table 16 it is inferred that, in general, the drape coefficient percentage was significantly higher in the cotton x hand spun pure UAS sheep breed wool (68.47) with lesser number of nodes (2) than the rest of the union fabrics. Among the hand spun union fabrics, the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric showed lower drape coefficient value (44.93) with 3 nodes than the control union fabric (68.47) which clearly indicated that the former fabric draped gracefully than the later fabric. The CV percentage was found to be less in hand spun union fabric (3.20) than the friction spun union fabrics (5.39). However in the friction spun union fabrics, cotton x UAS sheep breed wool/ jute (60/40) fabric exhibited slightly higher drape coefficient value (40.31) than the control sample (39.17). However, both fabrics draped in graceful folds with 3 nodes.

Table 14a: Influence of yarn count and cloth count on the cloth tensile strength of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

	Source		Warp				Weft			
		Variables	Coefficients	Standard Error	t test	p-value	Coefficients	Standard Error	t test	p-value
1.	Hand spun Cotton x pure UAS sheep breed wool union fabric	X_1	-13.809	4.014	-3.441^{**}	0.011	1.497	0.980	1.527^{NS}	0.171
		X_2	-0.118	0.388	-0.305^{NS}	0.769	0.356	0.354	1.004^{NS}	0.348
		R^2	0.632				0.316			
2.	Hand spun Cotton x UAS sheep breed wool/ r-PET (70/30) union fabric	X_1	0.416	0.993	0.419^{NS}	0.688	1.405	0.716	1.963^{NS}	0.090
		X_2	-0.516	0.323	-1.597^{NS}	0.154	0.233	0.238	0.983^{NS}	0.359
		R^2	0.271				0.385			
3.	Friction spun cotton x pure UAS sheep breed wool union fabric	X_1	-2.364	3.555	-0.665^{NS}	0.527	1.018	0.609	1.673^{NS}	0.138
		X_2	-0.200	0.428	-0.467^{NS}	0.655	0.212	0.164	1.293^{NS}	0.237
		R^2	0.067				0.317			
4.	Friction spun cotton x UAS sheep breed wool/ jute (60/40) union fabric	X_1	1.117	0.667	1.675^{NS}	0.138	-0.495	0.307	-1.613^{NS}	0.151
		X_2	-1.1×10^{-16}	0.325	$-3.5 \times 10^{-16**}$	1.000	0.250	0.171	1.463^{NS}	0.187
		R^2	0.359				0.325			

** Significant at 1 per cent level NS- Non-significant

X_1 – Yarn count X_2 – Cloth count R^2 – Coefficient of determination

Table 15: Cloth elongation (%) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Cloth elongation (%)	
			Warp way	Weft way
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	18.52	10.07
		Cotton x UAS sheep breed wool/ r-PET (70/30)	19.02	8.30
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	15.80	13.51
		Cotton x UAS sheep breed wool/ jute (60/40)	17.94	18.75

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Warp	0.357	0.104*	4.252
	Weft	0.228	0.066*	5.562
Friction spun union fabrics	Warp	0.208	0.061*	2.758
	Weft	0.323	0.094*	4.474

*Significant at 5 per cent level

Table 15a: Influence of yarn count and cloth count on the cloth elongation of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Union fabrics		Warp				Weft			
		Variables	Coefficients	Standard Error	t test	p-value	Coefficients	Standard Error	t test	p-value
1.	Hand spun Cotton x pure UAS sheep breed wool	X_1	0.782	2.007	0.389^{NS}	0.708	-0.634	0.468	-1.354^{NS}	0.218
		X_2	-0.059	0.193	-0.305^{NS}	0.769	-0.033	0.169	-0.194^{NS}	0.851
		R^2	0.033				0.209			
2.	Hand spun Cotton x UAS sheep breed wool/ r-PET (70/30)	X_1	-1.571	0.416	-3.776**	0.007	1.557	0.594	2.622*	0.034
		X_2	0.219	0.135	1.623^{NS}	0.149	-0.040	0.197	-0.204^{NS}	0.844
		R^2	0.691				0.507			
3.	Friction spun cotton x pure UAS sheep breed wool	X_1	-1.118	0.637	-1.754^{NS}	0.123	-0.018	0.345	-0.053^{NS}	0.959
		X_2	-0.069	0.076	-0.901^{NS}	0.398	-0.032	0.093	-0.344^{NS}	0.741
		R^2	0.310				0.018			
4.	Friction spun cotton x UAS sheep breed wool/ jute (60/40	X_1	-0.073	0.293	-0.250^{NS}	0.809	-1.319	0.651	-2.025^{NS}	0.082
		X_2	-4.51×10^{-17}	0.142	-3.2×10^{-16}**	1.000	0.362	0.363	0.999^{NS}	0.351
		R^2	0.012			0.371				

** Significant at 1 per cent level
*Significant at 5 per cent level
NS- Non-significant

X_1 – Yarn count
X_2 – Cloth count
R^2 – Coefficient of determination

Table 16: Cloth drapability (%) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Nodes	Cloth drape coefficient (%)
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	2	68.47
		Cotton x UAS sheep breed wool/ r-PET (70/30)	3	44.93
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	3	39.17
		Cotton x UAS sheep breed wool/ jute (60/40)	3	40.31

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Cloth drape coefficient (%)	0.812	0.237*	3.203
Friction spun union fabrics		0.960	0.280*	5.399

*Significant at 5 per cent level

Influence of cloth bending length, cloth crease recovery and cloth weight on the cloth drape coefficient of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Table 16a depicts the influence of cloth bending length, cloth crease recovery and cloth weight on the cloth drape coefficient of test samples. It is revealed from the table that there exists a relation between independent and dependent variables, except bending length showed no significant relation with drape coefficient of the test samples. However the cloth crease recovery in warp way negatively significant in the hand spun union fabrics which indicating higher the cloth crease recovery lower the drape coefficient of the samples. Whereas, the crease recovery in weft way significantly influence on drape coefficient of the hand spun cotton x pure UAS sheep breed wool union fabric with negative relation and positively significant in hand spun cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) and friction spun cotton x pure UAS sheep breed wool samples. The cloth weight significantly influence on drapability of test samples expect cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric. There was no influence of cloth bending length, cloth crease recovery and cloth weight on drape coefficient of the sample. The R^2 values for cotton x pure UAS sheep breed wool union fabrics (99 % - friction spun and 97 % - handspun).

4.5.4 Cloth abrasion strength (cycles) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Abrasion is an aspect of wear. It is the rubbing away of the component fibres and yarns of the fabric. The abrasive wear of the material depends on the type of fibre, fibre properties, yarn twist and fabric structure. It also depends on abrasion tests factors *viz.,* type of abrasion, abradant, pressure, speed and direction of the machine. The life of a fabric is dependent on its resistance to abrasion.

Table 17 reveals the abrasion strength of cotton x hand spun and friction spun pure wool and blended union fabrics. The cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) sample showed higher resistance to abrasion (688 cycles) followed by cotton x hand spun pure wool (628), cotton x friction spun wool/ jute (548) and cotton x friction spun pure wool (380) sample.

The loss in thickness of the union fabrics on abrasion expressed in terms of percentage and was relatively higher in cotton x pure UAS sheep breed wool (3.76) followed by cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (3.15), cotton x friction spun pure UAS sheep breed wool (1.79) and cotton x friction spun UAS sheep breed wool/ jute union fabric (1.28).

Whereas the loss in mass of cotton x friction spun pure UAS sheep breed wool was found to be slightly higher (0.55) than the cotton x hand spun pure UAS sheep breed wool (0.36) fabric, followed by cotton x friction spun UAS sheep breed wool/ jute (0.32) and cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (0.29) samples.

Influence of yarn count and cloth thickness on the loss in weight and loss in thickness of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Influence of yarn count and cloth thickness on the loss in weight and loss in thickness of test samples is presented in Table 17a. It was noticed from the table that, the yarn count and cloth thickness does not influence on loss in weight and loss in thickness of the test samples expect cotton x friction spun pure UAS sheep breed wool union fabric, in which the loss in thickness significantly do influenced by yarn count and cloth thickness with R^2 (61 %) at 1 per cent level with positive relation *i.e.,* increase in yarn count resulting into increase in loss in weight.

Table 16a : Influence of cloth bending length, cloth crease recovery and cloth weight on the cloth drape coefficient of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

	Union fabrics	Cloth drape coefficient				
		Variables	Coefficients	Standard Error	t test	p-value
1.	Hand spun Cotton x pure UAS sheep breed wool union fabric	X_1	0.143	0.711	0.201^{NS}	0.850
		X_2	-0.883	0.660	-1.337^{NS}	0.252
		X_3	-0.170	0.020	-8.475**	0.001
		X_4	-0.600	0.172	-3.480**	0.025
		X_5	3.609	1.521	2.372*	0.076
		R^2	0.973			
2.	Hand spun Cotton x UAS sheep breed wool/ r-PET (70/30) union fabric	X_1	-4.596	5.151	-0.892^{NS}	0.422
		X_2	-0.493	2.548	-0.193^{NS}	0.856
		X_3	-0.349	0.127	-2.754*	0.051
		X_4	0.168	0.070	2.377*	0.076
		X_5	-76.857	13.465	-5.707**	0.005
		R^2	0.911			
3.	Friction spun cotton x pure UAS sheep breed wool union fabric	X_1	0.581	0.833	0.697^{NS}	0.524
		X_2	-0.493	1.192	-0.414^{NS}	0.700
		X_3	-0.098	0.082	-1.206^{NS}	0.294
		X_4	0.467	0.021	22.172**	2.45E-05
		X_5	129.215	14.348	9.005**	0.000
		R^2	0.993			
4.	Friction spun cotton x UAS sheep breed wool/ jute (60/40) union fabric	X_1	0.804	6.440	0.124^{NS}	0.907
		X_2	-0.536	5.684	-0.094^{NS}	0.929
		X_3	0.046	0.213	0.219^{NS}	0.837
		X_4	-0.003	0.134	-0.028^{NS}	0.978
		X_5	57.196	35.35	1.617^{NS}	0.181
		R^2	0.597			

** Significant at 1 per cent level *Significant at 5 per cent level NS- Non-significant

X_1 – Cloth bending length (Warp) X_2 - Cloth bending length (Weft) X_3 – Cloth crease recovery (Warp) X_4 - Cloth crease recovery (Weft)

X_5 – Cloth weight R^2 – Coefficient of determination

Table 17: Cloth abrasion strength (cycles) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Number of cycles	Loss in mass (%)	Loss in thickness (%)
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	628	0.36	3.76
		Cotton x UAS sheep breed wool/ r-PET (70/30)	688	0.29	3.15
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	380	0.55	1.79
		Cotton x UAS sheep breed wool/ jute (60/40)	548	0.32	1.28

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Loss in mass (%)	0.028	0.008*	18.810
	Loss in thickness (%)	0.189	0.055*	12.238
Friction spun union fabrics	Loss in mass (%)	0.078	0.023*	43.824
	Loss in thickness (%)	0.247	0.072*	34.130

*Significant at 5 per cent level

Table 17a: Influence of yarn count and cloth thickness on the cloth abrasion resistance of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

	Union fabrics		Cloth abrasion resistance			
		Variables	Coefficients	Standard Error	t test	p-value
Loss in weight	Hand spun Cotton x pure UAS sheep breed wool union fabric	X_1	0.155	0.180	0.862^{NS}	0.417
		X_2	0.873	0.792	1.101^{NS}	0.306
		R^2	0.229			
	Hand spun Cotton x UAS sheep breed wool/ r-PET (70/30) union fabric	X_1	0.003	0.010	0.341^{NS}	0.742
		X_2	0.094	0.105	0.895^{NS}	0.400
		R^2	0.117			
	Friction spun cotton x pure UAS sheep breed wool union fabric	X_1	0.259	0.161	1.604^{NS}	0.152
		X_2	1.003	1.432	0.700^{NS}	0.506
		R^2	0.268			
	Friction spun cotton x UAS sheep breed wool/ jute (60/40) union fabric	X_1	0.174	0.207	0.840^{NS}	0.428
		X_2	1.709	2.156	0.792^{NS}	0.454
		R^2	0.107			
Loss in thickness	Hand spun Cotton x pure UAS sheep breed wool union fabric	X_1	-0.048	0.056	-0.862^{NS}	0.417
		X_2	-0.272	0.247	-1.101^{NS}	0.306
		R^2	0.229			
	Hand spun Cotton x UAS sheep breed wool/ r-PET (70/30) union fabric	X_1	0.199	0.582	0.341^{NS}	0.742
		X_2	5.131	5.728	0.895^{NS}	0.400
		R^2	0.117			
	Friction spun cotton x pure UAS sheep breed wool union fabric	X_1	2.206	0.681	3.235**	0.014
		X_2	4.848	6.044	0.802^{NS}	0.448
		R^2	0.610			
	Friction spun cotton x UAS sheep breed wool/ jute (60/40) union fabric	X_1	-0.004	0.004	-0.840^{NS}	0.428
		X_2	-0.039	0.050	-0.792^{NS}	0.454
		R^2	0.107836			

** Significant at 1 per cent level NS- Non-significant

X_1 – Yarn count X_2 – Cloth count R^2 – Coefficient of determination

4.5.5 Cloth pilling (ratings) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Pilling is a fabric surface fault characterized by little pills of entangled fibre clinging to the cloth surface and giving the garment unaesthetic appearance. The pills are formed during wear and washing by the entanglement of loose fibres which protrudes from the fabric surface. Under the influence of the rubbing action these loose fibres develop in to small spherical bundles anchored to the fabric by a few unbroken fibres in the form of pills (Booth, 1996).

Table 18 shows the resistance of samples for pilling. The hand spun union fabrics (cotton x pure UAS sheep breed wool and cotton x UAS sheep breed wool/ recycled polyethylene terephthalate) and cotton x friction spun pure UAS sheep breed wool possessed moderate pilling (rating 3). Whereas, slight pilling was observed in cotton x friction spun UAS sheep breed wool/ jute (60/40) blended union fabric (rating 2).

4.5.6 Cloth air permeability (cm^3 / cm^2 / sec) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The air permeability of a fabric is a measure of how well it allows the passage of air through it. The ease of passage of air is of importance for a number of fabric end uses such as industrial filters, tents, sailcloths, parachutes, raincoat materials, shirtings, downproof fabrics and air bags (Saville, 2004).

Significantly higher amount of air was passed in cotton x UAS sheep breed wool blended union fabrics than control samples (Table 19).

Among all the union fabrics, the greater amount of air was passed in the cotton x friction spun pure UAS sheep breed wool/ jute (60/40) union fabric (125.60) followed by friction spun control sample (123.80). The cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (85.70) and cotton x hand spun pure wool handspun (76.64) union fabrics showed significantly lower air permeability rate than the friction spun union fabrics.

4.5.7 Cloth thermal insulation value (tog) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

The insulation value of a fabric is in fact mainly dependent on its thickness. The insulation value of clothing when it is worn is not just dependent on the insulation value of each individual garment but on the whole outfit as the air gaps between the layers of clothing can add considerably to the total insulation value. This assumes that the gaps are not so large that air movement can take place within them, leading to heat loss by convection. Because of this limitation the closeness of fit of a garment has a great influence on its insulation value as well as the fabric from which it is constructed (Saville, 2004).

It was noticed from the table 20 that, thermal insulation value was significantly high in the hand spun union fabrics than the friction union fabrics.

Among the handspun union fabrics, the control sample exhibited higher thermal insulation value (26.38) than the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate fabric (18.47). Comparatively least thermal insulation value was found in the friction spun union fabrics *i.e.,* control sample (10.91) and cotton x UAS sheep breed wool/ jute (7.20).

Table 18: Cloth pilling (ratings) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Cloth pilling (ratings)
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	3
		Cotton x UAS sheep breed wool/ r-PET (70/30)	3
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	3
		Cotton x UAS sheep breed wool/ jute (60/40)	2

Ratings

1 - No pilling
2 - Slight but tolerable pilling
3 - Moderate pilling
4 - Severe pilling
5 - Extremely high pilling

Table 19: Cloth air permeability (cm^3 / cm^2 / sec) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Cloth air permeability (cm^3 / cm^2 / sec)
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	76.64
		Cotton x UAS sheep breed wool/ r-PET (70/30)	85.70
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	123.80
		Cotton x UAS sheep breed wool/ jute (60/40)	125.60

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Cloth air permeability	1.273	0.359*	3.507
Friction spun union fabrics		1.581	0.461*	2.835

*Significant at 5 per cent level

4.6 Cost of production of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Table 21 records the production cost of cotton x wool hand and friction spun union fabrics. The variable inputs such as raw material, preparatory, weaving charges and overhead expenses were taken into consideration for the calculation of production cost of woven samples.

The production cost of hand spun union fabrics was found to be more compared to friction spun union fabrics. Among the hand spun union fabrics, the production cost of control sample was comparatively higher (Rs. 346.78/ meter) than the cotton x wool/ recycled polyethylene terephthalate (70/30) union fabric (Rs. 332.56/ meter). Among the friction spun union fabrics, the production cost was high in case of cotton x wool/ jute (60/40) union fabric (Rs. 278.94/ meter) than the control sample (Rs. 272.78/ meter).

The selling price of hand spun union fabrics (Rs. 473.00 and 454.00/ meter) were relatively more than the friction spun union fabrics (Rs. 381.00 and Rs. 372.00/ meter).

In general, the raw material cost was contributed greater percentage for the production of union fabrics followed by preparatory and weaving charges.

Table 20: Cloth thermal insulation value (tog) of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Sl. No.	Type of spinning	Union fabrics	Cloth thermal insulation value (tog)
1	Hand spun union fabrics	Cotton x pure UAS sheep breed wool (Control 1)	26.38
		Cotton x UAS sheep breed wool/ r-PET (70/30)	18.47
2	Friction spun union fabrics	Cotton x pure UAS sheep breed wool (Control 2)	10.91
		Cotton x UAS sheep breed wool/ jute (60/40)	7.20

ANOVA

Type of spinning	Variables	Sem ±	CD (5 %)	CV (%)
Hand spun union fabrics	Cloth thermal insulation value	1.566	0.457*	15.618
Friction spun union fabrics		0.554	0.162*	13.685

*Significant at 5 per cent level

Table 21: Economics of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

(Rs. /m)

Sl. No.	Particulars	Union fabrics			
		Hand spun		Friction spun	
		Cotton x pure UAS sheep breed wool	Cotton x UAS sheep breed wool/ r-PET (70/30)	Cotton x pure UAS sheep breed wool	Cotton x UAS sheep breed wool/ jute (60/40)
I.	**Variable cost**				
a.	Raw material				
	Warp (cotton)	211.20	202.80	196.80	201.60
	Weft	63.23	59.06	9.88	11.19
b.	Preparatory processes				
i.	Winding charges	12.35	10.70	6.10	6.15
ii.	Warping charges	25.00	25.00	25.00	25.00
iii.	Drawing and denting	15.00	15.00	15.00	15.00
c.	Weaving	20.00	20.00	20.00	20.00
II.	**Total variable cost in Rs.**	**346.78**	**332.56**	**272.78**	**278.94**
III.	Overhead expenses (5%)	17.34	16.63	13.64	13.95
IV.	**Total Production cost in Rs.**	**364.12**	**349.19**	**286.42**	**292.89**
V.	Profit (30%)	109.24	104.76	85.93	87.87
VI.	**Selling price (In Rs.)**	**473.36**	**453.95**	**372.35**	**380.76**

Note:

Cost of the cotton (2/20s)/ kg (warp)	Rs. 1200
Cost of the hand spun pure UAS sheep breed wool/ kg (weft)	Rs. 256.00
Cost of the hand spun UAS sheep breed wool/ r-PET (70/30)/ kg (weft)	Rs. 275.50
Cost of the friction spun pure UAS sheep breed wool/ kg (weft)	Rs. 81.00
Cost of the friction spun UAS sheep breed wool/ jute (60/40)/ kg (weft)	Rs. 91.00

5. DISCUSSION

Findings of the present study titled “Quality assessment of UAS sheep breed wool blends” are discussed under following headings:

5.1 Assessment of physical properties of pure UAS sheep breed wool and blended yarns

5.2 Assessment of mechanical properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

5.3 Assessment of functional properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

5.4 Cost of production of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

5.1 Assessment of physical properties of pure UAS sheep breed wool and blended yarns

Effect of blend ratio on yarn count (Nm) of the pure UAS sheep breed wool and blended yarns

In general the friction spun pure and blended yarns (4.90 – 13.08) were finer than the hand spun pure and blended yarns (2.26 – 6.48). This may be due to constant speed of the friction spinning machine.

However, the hand spun pure wool yarn showed least yarn count (2.26) among all the test samples due to crimped configuration of the wool which prevents the wool fibres aligning themselves too closely when being spun into yarn (Gohl and Vilensky, 2005).

Among the hand spun blended yarns, the yarn linear density was significantly higher in case of UAS sheep breed wool/ recycled polyethylene terephthalate (50/50) blend ratio compared to other hand spun blended yarns. Irrespective of spinning methods, the yarns become finer as recycled polyethylene terephthalate percentage increases in the blend ratio. This may be owing to fibre content *i.e.,* recycled polyethylene terephthalate has the uniform fibre diameter and lower length variation contributes finer yarn count. Similar results were noticed by Samanta (2014).

Among the friction spun pure and blended yarns, the coarser yarn count was noticed in the UAS sheep breed wool/ jute (50/50) blended yarn. In this case, as percentage of jute fibre increases in the blend ratio, the yarns become coarser. This may be due to combined effect of jute and wool fibre diameter (39.65µ and 30.54µ, Table 1) and jute has less cohesive property that prevents the optimum blending with wool fibres.

Effect of blend ratio on yarn twist (tpi) of the pure UAS sheep breed wool and blended yarns

Table 4 depicts the maximum tpi in the friction spun pure and blended yarns compared to hand spun yarns due to the uniform sliver feeding, constant pressure and uniform speed of the friction spinning machine during spinning operation. Similar results were reported by Goel (2015).

The least yarn tpi was noticed in the hand spun pure UAS sheep breed wool yarn (4.18) because of better cohesive property of wool fibres due to which fibres easily cling together with less amount of tpi (Gohl and Vilensky, 2005).

The friction spun UAS sheep breed wool/ recycled polyethylene terephthalate yarns exhibited higher twists per inch than the other blended yarns due to finer yarn count resulting into higher twist level. However, the ideal amount of twist varies with the yarn count and thickness: finer the yarn count, higher the yarn tpi.

Effect of blend ratio on single yarn strength (kgf) of the pure UAS sheep breed wool and blended yarns

Table 5 showed that the pure wool yarns (control) spun on different spinning methods obtained lower tenacity values (0.26 and 0.25) than the blended yarns. This may be due to polymer system of the wool fibre *i.e.,* 70 - 75 per cent of amorphous region and formation of few hydrogen bonds in wool fibre which contributes to lower strength. These results are in confirmation with work of Gohl and Vilensky (2005).

Irrespective of fibre content and blend ratio, the friction spun blended yarns showed lower tenacity than the hand spun blended yarns which may be due to coarseness and bulkiness of hand spun yarns than the friction spun yarns contributing to greater tenacity and vica versa.

In case of friction spun UAS sheep breed wool/ acrylic blended yarns, it was seen that as the wool percentage decreased with acrylic content and the tenacity value increased (50/50 - 0.55, 60/40 - 0.27, 70/30 - 0.22). This may be due to fibre polymer orientation of acrylic and wool. Acrylic fibre has better polymer orientation contributing to higher crystallinity and greater tenacity compared to wool. Among the UAS sheep breed wool/ recycled polyethylene terephthalate blends, as the wool per cent decreased recycled polyethylene terephthalate content increased and the strength of the yarn decreased. The decrease in strength is due to less tenacity of the recycled polyethylene terephthalate fibres (3.73) than the wool (3.88, Table 1). Similar results were also recorded by Telli and Ozdil (2013).

However mixed trend was noticed in UAS sheep breed wool/ jute blends *i.e.,* hand and friction spun yarns of 60/40 blend ratio possessed higher tenacity (0.35 and 0.49) may be due to combined effect of yarn count and twist level.

Effect of blend ratio on yarn elongation (%) of the pure UAS sheep breed wool and blended yarns

In general friction spun pure and blended yarns possessed greater percentage of elongation than the hand spun pure and blended yarns (Table 6). High twist insertion in friction spun yarn is due to high speed and constant pressure in drawing and twisting during friction spinning. These results are in confirmity with results of Goel (2015).

Among the pure and blended hand spun yarns, the mean value of UAS sheep breed wool/ acrylic (5.51) and UAS sheep breed wool/ recycled polyethylene terephthalate (4.66) showed greater elongation percentage than the UAS sheep breed wool/ jute (1.47) blends. This may due to combined effect of crimped configuration, yarn count (4.34 and 4.53) and yarn tenacity (0.52 and 0.59 mean strength) of UAS sheep breed wool/ acrylic and UAS sheep breed wool/ recycled polyethylene terephthalate blends.

The least elongation was noticed in the hand spun UAS sheep breed wool/ jute blends due to the stiffness and coarser yarn count of the UAS sheep breed wool/ jute blended yarns. These findings are in line with Goel *et al.* (2011).

Among the friction spun blended yarns, the greater percentage of elongation was found in UAS sheep breed wool/ jute (60/40) blended yarns (18.84) due to higher yarn strength (0.49). The least elongation percentage was noticed in UAS sheep breed wool/ recycled polyethylene terephthalate blend ratios due to low fibre strength (3.73, Table 1).

Effect of blend ratio on yarn evenness of the hand spun pure UAS sheep breed wool and blended yarns (Table 7a)

- Unevenness percentage (U %)

More unevenness percentage (39.30) was seen in UAS sheep breed wool/ acrylic (60/40) blends which may due to the waviness present in acrylic leads to difficulty in fibre opening process resulting into bulkier and more yarn evenness.

- Thick places/ km (+ 50 %)

Higher number of thick places were noticed in the UAS sheep breed wool/ recycled polyethylene terephthalate (50/50) blended yarn due to fineness variation *i.e.,* finer recycled polyethylene terephthalate (12.61 µ) and coarser wool (30.54 µ). And also due to high twisting force and low fibre movement leading to formation of thick places. These findings are in line with Ochola *et al.* (2012).

- Thin places/ km (- 50 %)

The UAS sheep breed wool/ acrylic blends show comparatively more number of thin places (10369.70) than other blends which may be due to lack of homogeneity in the fibre fineness of the constituent fibres in the UAS sheep breed wool/ acrylic blends (Wool - 30.54, acrylic - 11.81, Table 1).

- Neps/ km (+ 200 %)

The hand spun UAS sheep breed wool/ acrylic (60/40) blended yarn registered more number of neps as compared to other test samples. This increase in the neps may be due to combined effect of coarser wool and finer acrylic fibre with lower flexural rigidity making the acrylic fibres easy to curl leading to form more number of neps after releasing from the high stress during yarn spinning. These results are in configuration with the results reported earlier by Samanta (2014).

Whereas, less number of neps were noticed in the UAS sheep breed wool/ jute blends of 60/40 ratio (164.40) due to the lower linear density of the yarn. The coarser yarn showed the lesser neps than the finer yarns. The results are in line with the work of Ochola *et al.* (2012) who stated that the linear density has influence on the number of neps which implies that coarser yarn results lesser neps than the finer yarns.

- Total imperfections

However least unevenness percentage was found in UAS sheep breed wool/ jute blends (2480.00) followed by thick and thin places (952.00 and 2415.30), neps (202.20) and total imperfections (3677.10) indicating more even yarn. This may be because of higher flexural rigidity of jute fibres which makes it stiffer than the wool and significantly reduces the chance of entanglement during fibre separation process leading to more even yarns.

Effect of blend ratios on yarn evenness of the friction spun pure UAS sheep breed wool and blended yarns (Table 7b).

- Unevenness percentage (U %)

Among the pure UAS sheep breed wool and blended yarns, the unevenness percentage was relatively high in case of UAS sheep breed wool/ acrylic yarns due to waviness and bulkier UAS sheep breed wool/ acrylic that creates several problems *viz.,* excessive variation in fibre fineness and fibre length, improper mixture and fibres distribution during carding and gilling.

- Thick places/ km (+ 50 %)

Secondly, more amount of thick places formed in the UAS sheep breed wool/ recycled polyethylene terephthalate friction spun blends may be because of heterogeneous fibre fineness (recycled polyethylene terephthalate - 12.61µ and wool -30.54µ, Table 1).

- Thin places/ km (- 50 %), neps/ km (+ 200 %) and total imperfections

Lastly, friction spun blended yarn of wool/ recycled polyethylene terephthalate accounted higher number of thick and thin places, total imperfections compared to other test samples due to variations in the fibre properties (length and fineness) leading to poor blending and carding which yield greater total yarn imperfections.

In general, fibre content, blend ratio and method of spinning influences on physical properties of pure wool and blended yarns. Hence, the set hypothesis for the study is rejected.

5.2 Assessment of mechanical properties of cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Cloth count (Ne)

From the Table 9 it is clear that, irrespective of spinning methods, blend ratios and fibre content, the cotton x pure UAS sheep breed wool and blended union fabrics exhibited greater ends per inch than the picks per inch. Since warp being finer (2/20s ply) could be aligned more densely than the coarser fillings *i.e.,* pure UAS sheep breed wool and wool blends. Greater number of ends per unit area attributed to many important functional properties *i.e.,* drapability, serviceability like strength and cloth balance. However warp way thread density was found to be similar in all the cotton x UAS sheep breed wool blended union fabrics due to same reed (60s) employed to weave all the four union fabrics with better warp density and alignment.

Among the samples, hand spun union fabrics obtained lower cloth density both warp and weft way than the friction spun union fabrics. This may be because of relatively coarser yarn count of hand spun UAS sheep breed wool (2.26) and (70/30) UAS sheep breed wool/ recycled polyethylene terephthalate (3.34, Table 3) which resulted into lesser number of threads per unit area.

Cloth weight (GSM)

An appraisal of Table 10 showed that the hand spun *i.e.,* cotton x pure UAS sheep breed wool union fabric possessed more weight (428.00) which may be due to the coarser yarn count of the pure UAS sheep breed wool yarn (2.26) and starched cotton warp yarns adds weight to the fabric.

However, the lowest cloth weight was seen in the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric (388) which may be attribute to relatively finer yarn count (3.34) than pure UAS sheep breed wool (2.26). Eventhough ends and picks per inch were high in cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric, the cloth weight was less may be because of finer yarn count.

Further, in case of friction spun union fabrics, the cotton x UAS sheep breed wool/ jute (60/40) union fabric exhibited significantly heavier than the control fabric due to combined effect of coarser wool and hemicellulose content in jute resulting into heavier fabrics.

Cloth thickness (mm)

From the Table 11 it is observed that, the hand spun cotton x hand spun pure UAS sheep breed wool exhibited maximum thickness (2.64) than the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate sample (2.16) due to coarser yarn resulting in thicker fabrics. These are on par with the results of Sharma *et al.* (2015) who reported that the fabric thickness directly affected the yarn thickness indicating that fabric woven with coarser yarns eventually obtained thicker and heavier fabrics.

However the friction spun cotton x friction spun UAS sheep breed wool/ jute (60/40) material performed higher thickness (1.68) than the control sample *i.e.,* cotton x friction spun pure UAS sheep breed wool (1.64) due to the higher fabric weight of the cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric. Sharma and Pant (2013) noticed that, the fabric thickness increased with increase in the fabric weight.

Among the four union fabrics, the cotton x hand spun pure UAS sheep breed wool union fabric which was significantly thicker and heavier due to coarser yarn count of hand spun yarns adding little bulkiness to the fabric.

Cloth crease recovery angle (degree)

The recovery or resistance towards creasing largely depends on the fibre content, resiliency and presence of sizing material which makes the fabric stiff or pliable. The stiffer and thicker fabrics possessed lower recovery angle whereas soft and pliable fabric however exhibited greater recovery angle. In other words the cloth stiffness is inversely proportional to the crease recovery angle.

Among the union fabrics, weft way recovery was greater than the warp way because of wool and its blends. Wool fibre has excellent resiliency because of crimped configuration and partly due to the □– □ configuration of the polymers (Gohl and Vilensky, 2005).

Among the hand spun union fabrics, cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) samples possessed higher cloth recovery angle than the control due to combined effect of wool resiliency and recycled polyethylene terephthalate pliability. These results are supported by the values of bending length presented in the Table 12 where in cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) showed lesser bending length path (1.59, Table13) than the control sample (2.12).

In case of friction spun union fabrics, the control sample exhibited better cloth recovery (89.61) than the cotton x pure UAS sheep breed wool/ jute (60/40) sample (87.00). This may be due to soft and pliable nature of cotton and resilient properties of wool fibres. Whereas cotton x wool/ jute blended union fabric obtained lesser recovery angle owing to 40 per cent of jute fibre content that reduces the recovery angle. Frank (2005) observed that, the jute has very little recoverable elasticity properties compared to other fibres.

Cloth stiffness (cm)

From the Table 13 it is clear that, the cotton x hand spun pure UAS sheep breed wool fabric showed high bending length in warp and weft way (1.77 and 2.12) which may be because of the coarser yarn count used as filling/ weft for production of union fabrics. As the filling yarn diameter is increased, the more crimp is given to the warp yarn in the place perpendicular to the fabric surface attributed to higher stiffness of the fabric structure as a whole stated by Emin *et al.* (2008).

The lower bending path was observed in case of cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) blended fabric due to combined effect of pliable and soft cotton and finer recycled polyethylene terephthalate (3.34, Table 1) leading to lower flexural rigidity contributing lesser fabric stiffness.

In the friction spun union fabrics, the cotton x UAS sheep breed wool/ jute (60/40) union fabric (1.3 and 1.33) have higher bending path due to the hemicellulose content in the jute fibre resulting in more stiffer fabric. These results are on par with the earlier results reported by Koranne *et al*. (2013).

Whereas, the lower bending length of the control *i.e.,* cotton x pure UAS sheep breed wool union fabric was attributed to the crimp and partly to the amorphous nature of the polymer system of wool (Gohl and Vilensky, 2005).

5.3 Assessment of functional properties of the cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

Cloth tensile strength (kgf)

Cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric was found to be stronger than the control due to the presence of recycled polyethylene terephthalate content. The polyester fibre have possessed more crystalline polymer system that leads to formation of very effective Vander Waals forces resulting into very good tenacity of the recycled polyethylene terephthalate polymers (Gohl and Vilensky, 2005). Whereas, cotton x pure wool fabric possessed comparatively lesser strength (48.32 and 13.18) which may be due to the weaker wool fibres because of greater percentage of amorphous region (70 - 75 per cent) and hydrogen bonds in the wool polymer system.

In the friction spun union fabrics, the highest strength was seen in the cotton x UAS sheep breed wool/ jute (60/40) fabric (64.44 and 22.22) due to the combined effect of cotton (65 - 70 per cent crystalline) and jute polymer region and yarn strength of jute.

In general, warp way tensile strength was greater (64.44) than the weft way (23.88) owing to fibre content *i.e.,* cotton polymer system has higher crystalline region (65 - 70 per cent), coarser yarn count (2/20s) and starch content contributing to better strength than the wool blends.

Cloth elongation (%)

All the test samples, warp way elongation was found to be greater than the weft way due to combined effect of fibre content, yarn type (2 ply), yarn twist, strength and elongation of cotton yarns (Table 15). Two ply cotton yarn with higher twist, better strength and elongation was used as warp for construction of union fabrics.

The cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric showed relatively lower elongation percentage in weft way (8.30) due to the presence of recycled polyethylene terephthalate which is more plastic than elastic because of 65-70 per cent of the crystalline polymer system, hindering the movement of fibres when stretched (Gohl and Vilensky, 2005).

However, the cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric explored greater elongation percentage in both warp and weft way (17.94 and 18.75) due to the higher tenacity and elongation (0.49 and 18.84, Table 5 and 6) of the UAS sheep breed wool/ jute (60/40) yarn.

Cloth drapability (%)

The drapability of a fabric is influenced by many factors such as weave, cover factor, cloth thickness, cloth weight, bending length, finish etc. Fabrics with similar weave but different cover factor shows difference in drapability. The cloth stiffness is directly proportional to the drape quality. Drapability is expressed in terms of drape coefficient and number of nodes *i.e.,* higher drape coefficient, poor the drapability or greater the number of nodes, better the drapability. It means that, drape coefficient and the fabric drape are inversely related.

From the Table 16 it is learnt that, among the hand spun union fabrics, the control sample exhibited relatively higher drape coefficient value (68.47) probably because of high bending length (1.77 x 2.12, Table 13) and cloth thickness (2.64, Table 11). Thus it can be concluded that, greater the stiffness, higher is the drape coefficient. These results are in confirmity with results of Saville (2004). Whereas, the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric possessed least drape coefficient (44.93) attributed to low bending length (1.54 x 1.59, Table 13), low thickness (2.16, Table 11) thus flexible and pliable the fabric.

Among the friction spun union fabrics, both fabrics exhibited similar drape coefficient percentage *i.e.,* control sample (39.17) and cotton x UAS sheep breed wool/ jute (60/40) union fabric (40.31) with same number of nodes indicating draped gracefully than the hand spun union fabrics due to higher cloth density (Table 9), bending length (Table 13), less thick (Table 11) than the hand spun union fabrics.

Cloth abrasion strength (cycles)

Abrasion is just one aspect of wear and tear that in turn determines the durability of the cloth. Failure of the abrasion resistance is mainly due to weakening of the structure caused by mechanical breakdown of the individual fibres and the mechanism of break down is substantially the same for all fibres.

From the Table 17 it is noticed that, among the union fabrics, the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate union fabric exhibited higher resistance to abrasion with minimum loss in mass and thickness due to presence of recycled polyethylene terephthalate fibre content and optimum yarn twist considered to have good abrasion resistance. Savali B, P (2004) also reported that recycled polyethylene terephthalate with wool and cotton is found to increase their abrasion resistance at the expense of other properties.

Cloth pilling (ratings)

Generally a garment is not discarded because of a hole or a tear, but more after because of loss of appearance. One of the causes for loss of aesthetic appearance is pilling.

From Table 18 it is clear that irrespective of fibre content, blend ratio and spinning system, all the union fabrics showed slight to moderate pilling. This may be attributed to fibre content, yarn unevenness percentage and yarn total imperfections. The cotton x friction spun wool/ jute (60/40) union fabrics obtained slight pilling (rating - 2) due to better yarn evenness results *i.e.,* lower unevenness percentage (21.21) and total imperfections (5229.00).

Cloth air permeability (cm^3 / cm^2 / sec)

Air permeability rate was found to be more in friction spun union fabrics compared to hand spun union fabrics due to finer yarn count and more uniform weave structure of friction spun than the hand spun union fabrics (Table 19). Eventhough the hand spun union fabrics woven with less thread density, amount of air passed from the fabrics were low because of uneven surface structure of hand spun yarns. In the hand spun yarns more number of short staple wool fibres projected from the surface, which probably fills the openness of the weave on the surface of the fabric. Hence the less air flow was observed in the hand spun than the friction spun union fabrics.

Cloth thermal insulation value (tog)

The thermal insulation value was found to be significantly higher in case of cotton x hand spun pure wool union fabric than the rest of the fabrics (Table 20). Wool fabrics have better insulation property which provides warmthness due to more air spaces in the material occupying about two-thirds of the volume than to the fibres. This was supported by Gohl and Vilensky (2005).

In general, fibre content and method of spinning influences on mechanical and functional properties of union fabrics. Hence, the set hypothesis for the study is rejected.

5.4 Cost of production of developed cotton x hand spun and friction spun UAS sheep breed wool and blended union fabrics

The production cost of hand spun union fabrics was found to be more (Rs. 346.78/ meter) compared to friction spun union fabrics (Rs. 272.78/ meter) due to per kg cost of hand spun yarn (Rs. 256.00/ meter) was relatively higher than the friction spun yarn (Rs. 81.00/ meter). The labour charges for spinning of yarn on hand charaka was Rs. 200.00/ kg, whereas, the cost for friction spinning was Rs. 25.00/ kg of yarn. Thus friction spinning works out cheaper than the hand spinning but investment for friction spinning unit is high. Traditional hand spinning method is widely used in the study area with low investment and minimum skill. The hand spinning is encouraging enterprise in the rural areas to sustain the kambli weaving and to preserve and revive the heritage.

6. SUMMARY AND CONCLUSIONS

The present research titled “Quality assessment of UAS sheep breed wool blends” was conducted during the year 2014-2016 with the objectives to explore the spinning possibilities by blending UAS sheep breed wool with man-made fibre and natural fibre, to find out the physical properties of blended yarns, to develop plain woven blended fabrics, to assess the mechanical and functional properties of blended fabrics and to enumerate the cost of production of blended fabrics.

The sheared wool fleece was opened and scoured by using conventional two baths wool scouring machine. In the scoured bath, 3 per cent sodium carbonate and 2 per cent non ionic detergent keeping 1:40 MLR at 50^0C was maintained. The scoured and dried wool fibres were pre-carded and blended with acrylic, recycled polyethylene terephthalate and jute in various blend proportions *i.e.,* 70/30, 60/40 and 50/50 respectively. The sandwich/ stack blending method was adopted for blending wool and other fibres. The conditioned pure wool and blended fibres were subjected to woolen carding system, in which the fibre opening, gilling I and II and carding were followed. The carded slivers were further used for hand and friction spinning to develop pure and wool blended hand spun (1+9) and friction spun (1+9) yarns. The twenty pure and blended yarns were assessed for physical properties and yarn evenness. Based on the strength and total imperfections, one blended yarn and control (pure wool) from each spinning system were selected for production of union fabrics.

Four types of union fabrics were woven on handloom using 2/20s cotton as warp and one pure wool yarn and one wool blended yarn from each spinning system were used as weft. These woven union fabrics were than subjected for testing of mechanical and functional properties. The production cost was calculated based on variable and fixed cost.

The results of the present study are summarized as follows:

Physical testing of pure UAS sheep breed wool and blended yarns

- The hand spun pure and blended yarns exhibited coarser yarn count than friction spun pure and blended yarns
- The hand spun pure wool yarn possessed least yarn count and wool/ recycled polyethylene terephthalate (70/30) blended yarn was finer. In friction spun yarns, the wool/ acrylic blended yarns possessed finer yarn count compared to wool/ recycled polyethylene terephthalate and wool/ jute blends
- In general higher tpi observed in the friction spun yarns when compared to hand spun pure and blended yarns. In the hand spun UAS sheep breed wool and blended yarns, the wool/ acrylic (70/30) yarns exhibited higher tpi and friction spun wool/ recycled polyethylene terephthalate (50/50) explored the maximum tpi than the pure and blended yarns
- With respect to method of spinning, the friction spun blended yarns showed lower strength than the hand spun blended yarns. Among the hand spun yarns, the wool/ recycled polyethylene terephthalate (70/30) blended yarn attained highest tenacity value than other blends. Whereas the friction spun wool/ acrylic (50/50) blended yarn explored maximum strength as compared to pure and blended yarns

- Greater yarn elongation was found in the friction spun blended yarns than the hand spun blends, Among the hand spun, the highest percentage of elongation was seen in the wool/ acrylic (60/40) blend ratio and in friction spun yarns, the wool/ jute (60/40) blended yarns registered higher percentage of elongation
- In hand spun yarns, the wool/ acrylic blended yarns were more uneven with greater number of thick places, neps and total imperfections. Higher number of thick places were found in the wool/ recycled polyethylene terephthalate blends
- The friction spun pure wool yarn exhibited more number of thin places compared to other blended yarns. Whereas the wool/ acrylic (70/30) blends possessed higher percentage of unevenness and wool/ recycled polyethylene terephthalate (70/30) blends resulted greater number of thick places, neps and total imperfections
- The UAS sheep breed wool/ jute blends of hand spun and friction spun exhibited more even yarns with less number of total imperfections
- The friction spun pure UAS sheep breed wool and blended yarns were found to be more even than the hand spun yarns with less number of total imperfections

Mechanical properties of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

- Friction spun union fabrics were densely woven than hand spun union fabrics. However, the warp density of all union fabrics remained same, whereas the weft density varied
- All samples possessed relatively similar picks among the hand spun and friction spun union fabrics
- Amongst all union fabrics, the cotton x hand spun pure UAS sheep breed wool union fabric was heavier
- The hand spun union fabrics found to be thicker than the friction spun union fabrics
- The cloth thickness of control sample was higher than the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric
- The union fabric of cotton x friction spun UAS sheep breed wool/ jute (60/40) was thicker than the control
- Among all the union fabrics, the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric showed greater cloth crease recovery in both warp and weft directions than the other fabrics
- Cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric exhibited higher cloth recovery than control
- In friction spun union fabrics, the higher cloth recovery was found in the cotton x pure UAS sheep breed wool union fabric than the cotton x UAS sheep breed wool/ jute (60/40) union fabric
- Irrespective of spinning methods, hand spun union fabrics showed higher bending length compared to other union fabrics
- In the hand spun union fabrics, the control sample exhibited maximum bending length in warp and weft way than the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric

- The cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric showed greater bending length than the control

Functional properties of developed cotton x hand spun and friction spun pure UAS sheep breed wool and blended union fabrics

- Tensile strength was high in warp way than the weft way in all the developed union fabrics. The friction spun union fabrics possessed higher tensile strength than the hand spun union fabrics
- The highest tensile strength in both warp way and weft way was observed in the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric than the control. Cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric showed greater tensile strength in warp way and weft way than the control
- The warp way elongation percentage was high in all the union fabrics depicted higher elongation than all the samples
- In hand spun union fabrics, control sample explored higher percentage of elongation than the cotton x UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) union fabric
- In friction spun union fabrics, the cotton x UAS sheep breed wool/ jute (60/40) fabric exhibited higher elongation percentage than the control sample
- The friction spun union fabrics have greater drapability with less drape coefficient than the hand spun union fabrics
- Cotton x hand spun UAS sheep breed wool fabric showed highest drape coefficient than the cotton x hand spun UAS sheep breed wool/ recycled polyethylene terephthalate (70/30) fabric
- The cotton x hand spun wool/ recycled polyethylene terephthalate (70/30) sample showed higher resistance to abrasion than the other union fabrics with least loss in weight
- The cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric showed good resistance to abrasion resulting less percentage of loss in weight and thickness than the control sample
- All four union fabrics exhibited moderate better pilling resistance with rating 3. Cotton x friction spun UAS sheep breed wool/ jute (60/40) union fabric showed better resistance to pilling (rating 2)
- Friction spun union fabrics possessed higher air permeability value than the hand spun union fabrics
- The least value of air permeability was seen in the cotton x hand spun UAS sheep breed wool fabric among all the union fabrics
- Higher value of thermal insulation was noticed in the cotton x hand spun UAS sheep breed wool fabric among all the union fabrics
- Control samples of hand and friction spun union fabrics exhibited greater thermal insulation value than the blended union fabrics
- Production cost of hand spun union fabrics was found to be more compared to friction spun union fabrics

Implications and recommendations

Effective utilization of UAS sheep breed wool for production of union and blended fabrics has wide scope and importance in woolen industries and sheep rearing in view of marginal profit to the shepherd as well as kambli weavers of Northern Karnataka. Kambli weaving is one of the oldest cottage industry in the state provides greater employment to the many rural folk.

The UAS sheep breed wool has low tenacity and elongation than the other local breeds *i.e.,* Bannur and Deccani in the study area. The UAS fleece is softer and smoother, creamy white colour than the Deccani can be effectively blended with other natural and synthetic fibres to produce unique union fabrics.

The UAS sheep breed wool was blended with acrylic, recycled polyethylene terephthalate and jute with varied proportion (70/30, 60/40 and 50/50) and spun on hand and friction spinning systems. The hand spun blended yarns of 2-8 Nm has better strength and elongation. Whereas, the friction spun blended yarns with 4-12 Nm possessed better yarn evenness properties than the pure wool yarns.

The developed blended yarns can be effectively used as a weft to produce union fabrics with cotton as warp. This type of product development do not need any modification in existing spinning and weaving systems but provides several end use performance advantages. Union fabrics can be used to produce diversified products *viz.,* jackets, shawls, kamblis and warm clothes. Cost effective handloom UAS sheep breed wool union fabrics helps the handloom weavers to increase their earnings by adopting such new and simple technologies.

The cotton x pure wool and blended union fabrics exhibited better mechanical and functional properties than the Deccani wool products. The cotton-wool union fabrics possessed higher thermal insulation value and suitable as a clothing for moderate winter of tropical regions and summer season of temperate regions.

Suggestions for the future study

The following future studies can be taken up.

- The effect of enzyme treatment and subsequent chemical finishing of cotton/ wool union fabrics
- The application of natural antimicrobial agent on cotswool union fabrics can be studied
- The tailoring performance and hand feel of union fabrics can be studied through KAWABATA and FAST systems
- Production of variegated shawls and blankets by using hand and friction spun yarns

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QUALITY ASSESSMENT OF UAS SHEEP BREED WOOL BLENDS

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ABSTRACT

The present research was conducted during the year 2014-16 with the objectives to explore the spinning possibilities by blending University of Agricultural Sciences (UAS) sheep breed wool with man-made fibre and natural fibre, to find out the physical properties of blended yarns, to develop plain woven blended fabrics, to assess the mechanical, functional properties and to enumerate the cost of production of blended fabrics. To enhance the optimum utilization of UAS sheep breed fleece, the scoured wool fibres were blended with acrylic, r-PET and jute in varied blend proportions *i.e.,* 70/30, 60/40 and 50/50 respectively through sandwich technique. Pure and blended yarns were spun on hand charaka and friction spinning machine and subjected to physical properties *viz.,* yarn count, yarn twist, single yarn strength, elongation and yarn evenness. It was revealed that the friction-spun blended yarns exhibited improved fineness, greater twist, elongation and evenness than the hand-spun yarns. However, higher strength was seen in the hand-spun yarns compared to friction-spun yarns. Based on the strength and total yarn imperfections, blended yarns of hand-spun wool/ r-PET (70/30) and friction-spun wool/ jute (60/40) and pure wool yarn from each spinning system were selected for production of twill woven union fabrics. Four types of union fabrics were woven on handloom using 2/20s cotton as warp and blended yarns as weft and subjected to mechanical and functional properties. The hand-spun union fabrics exhibited heavier, thicker, greater cloth crease recovery, higher abrasion resistance and thermal insulation. The friction-spun union fabrics possessed higher tensile strength, elongation, drapability, air permeability and resistance to pilling. The production cost of hand-spun union fabrics (control sample - Rs. 346.78/ meter and cotton x wool/ r-PET (70/30) Rs. 332.56/ meter) were found to be more compared to friction-spun union fabrics (control sample - Rs. 272.78/ meter and cotton x wool/ jute (60/40) - Rs. 278.94 / meter).