Thus, the present study shows that the younger population is most affected by hair loss. Lifestyle related stress and pollution are the major factors responsible for hair loss, along with hardness of water which leads to scalp-related problems like dandruff and flaking. Majority of the population was unaware of the contribution of special diet, iron content, hormonal levels and genetic features to hair loss. It is imperative to generate awareness among the population regarding the causative factors, as persistent and long-term hair loss is an indicator of some physiological or environmental disturbances.

Conflict of interest: The authors declare no conflict of interest.

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A comparative study of physical properties of yarns and fabrics produced from fresh and recycled fibres

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Recycling is the process of producing new products with additional qualities from old materials which are no more in use. Furthermore, the decreasing natural resources forced researchers to produce new synthetic products from waste products using new technologies. This study compares the physical properties of yarns and fabrics produced using blends of fresh and recycled fibres/fabrics of wool, acrylic and polyester; these were used to manufacture fabrics through weaving technique. Physical properties of yarns, i.e. tensile strength, twist per inch of fabrics, i.e. tensile strength, elongation and bending length were measured and statistically analysed. The results showed that the physical properties of recycled yarns and fabrics were comparable to control/fresh yarns and fabrics. The strength of recycled yarns and fabrics was little different than control products. Thus, recycled yarns and fabrics can be used for the production of woollen apparels with suitable properties like smooth texture, appeal, etc.

Keywords: Fabrics, physical properties, recycling, yarns.

INDIA is the second largest producer of textiles and garments in the world and according to a report by Technopak Advisors the Indian textiles and apparel industry is expected to grow to about US$ 223 billion by 2021. The Indian textile industry is the oldest industry providing employment and earning foreign exchange for the country (http://info.shine.com/industry/textiles/17.html). As consumers are becoming more fashion-oriented, every year millions of garments are discarded because they are either worn out, damaged, outgrown or gone out of fashion. As a result, several textile and clothing items are disposed-off into the trash and end up in municipal landfills. Throwing away clothes is not only wasteful but also harmful for society and creates pollution problems.

For proper waste management and to generate minimum amount of waste, the waste hierarchy has taken many forms over the past decade; 'Reduce, Reuse and Recycle' are the three Rs in the waste hierarchy. Reduce is design for minimum use of energy, minimize or eliminate waste material. Reuse refers to the use an item more than once without reprocessing, which saves time, money,

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energy and resources. Recycle is the third component of hierarchy in which waste material is transformed into new products[1]. However, recycling of rags/old clothes is an innovative technique, where these are recycled for yarn-making. It is estimated that 99% of used textiles are recyclable. Rags are used by the shoddy industries for making yarn by the breakdown of fabric into fibres to make new products, and the reprocessed products are called 'shoddy'. The shoddy industries utilize natural as well as synthetic fibres for blending with yarn made out of re-spun rags, to provide strength to the yarn, thus deriving suitable yarn for required fabrics at an economical cost. The blending process varies for different purposes[2].

High-quality yarns can be manufactured from old clothes by blending with other natural or man-made fibres. Thus, these natural and synthetic fibres/fabrics can be utilized to made products like blankets, carpets, apparels, etc. using the weaving technique. In the recycling process, polyester is the main fibre/fabric for making usable products. Bartolome *et al.*[3] emphasized that by using polyester fibres/fabrics in the recycling process, it will be possible to reduce textile waste problem, the use of petrochemical products and also energy consumption. Many mechanical processes are applied to textile waste at the time of recycling, like tearing waste clothes and accessories from the garments to make fibres using tearing machines. In this study, wool, acrylic and polyester fibres were used as raw materials to produce fresh and recycled blended yarns of different yarn counts. These produced yarns were used for weaving of fabrics with different designs. These yarns and fabrics were tested for physical properties and compared with fresh and recycled yarns and fabrics.

Samples of different types of recycled woollen blended yarns were collected from shoddy yarn manufacturing units. A sample chart of the collected yarns was prepared and displayed. In order to know the preferences of experts regarding the collected blended yarn samples, preferential choice index was developed. The collected blended yarns were shown to a panel of 30 experts, which comprised of faculty members and PG students from Department of Textile and Apparel Designing, I. C. College of Home Sciences, CCS Haryana Agricultural University, Hisar, Haryana, India. Weighted mean scores were calculated for all the yarn samples according to the preferences obtained. On the basis of weighted mean scores, ranks were assigned to each sample of yarn and the most preferred blended yarn (wool : acrylic : polyester ratio of 53 : 18 : 28) was selected. One yarn of fresh/control fibres was also selected of the same ratio as recycled fibres.

Samples of different counts of the selected blended yarn being manufactured in the shoddy units were collected and again shown to the experts. Preferences of experts for selection of yarn count were sought using preferential choice index. The two top preferred yarn counts, i.e. 8 and 10 counts of the blended yarn of recycled and fresh/control fibres were selected for fabric construction.

Selected yarns were tested for strength and twist per inch using standards test methods. Woven fabrics were also tested to determine the physical properties like strength, elongation and bending length using standards test methods.

Data were statistically analysed using one-way analysis of variances (ANOVA) test. The data for different fabric tests were analysed on the basis of CD and their statistical significance were calculated using OP STAT software.

For making yarn, all the steps were included from sorting the rags to weaving for recycled yarns. The recycled yarns used in this study were obtained from waste (scraps) of shoddy industries. The scraps were torn through tearing machines and converted into fibrous form again and this was used for making yarns by blending with other synthetic fibres.

The tensile strength of yarns was tested with tensile strength tester (ASTM-D 2256-02). Yarn twists were tested using a twist tester. Five samples were tested and the mean value was reported. The strength and twists were calculated for each yarn, i.e. fresh yarn and recycled yarn (Table 1).

The fresh and recycled fabrics were woven from these yarns of 8 and 10 counts on a weaving machine at Panipat, Haryana. Tensile strength of fabrics was measured with a digital tensile strength tester according to ASTM D 2256-02. The same instrument was used for measuring the elongation of the fabrics. The bending length of the fabrics was also determined using stiffness tester according to ASTM-D 1388:1964. Statistical analysis of the data was done using OP STAT Software. The effect of tested parameters on the properties of fabrics was analysed using ANOVA test. The significant differences were also determined to check the difference between values. Data for different fabric tests were analysed on the basis of CD and their statistical significance were calculated using the OP STAT software.

The selected yarns of 8s and 10s were tested for twist per inch and strength, and compared with fresh yarn of same fibre composition and blend ratio.

Data on strength property of yarn elucidated in Table 2 indicate that the strength of blended control yarn is

Table 1. Equipment used[7]

Test	Instrument
For yarn testing	
Yarn strength	Tensile strength tester (ASTM-D 2256-02)
Yarn twist per inch	Twist tester
For fabric testing	
Tensile strength	Tensile strength tester (IS 4169:1975)
Elongation	Tensile strength tester (IS 4169:1975)
Bending length	Stiffness tester (ASTM-D 1388:1964)

slightly higher than recycled blended yarn of the same count. The strength of 8s control and recycled yarn was 1.04± and 0.8± gf respectively, whereas for 10s yarn, it was 2.02± and 1.04± gf respectively.

It can be concluded that there was minor difference in the strength of yarns as rags were used for manufacturing recycled yarns. When the blend of acrylic and polyester was evaluated, it was found that yarn mixed with fresh fibres had higher tensile strength. This may be attributed to the higher tensile strength values of blend of fresh yarns compared to recycled yarns of the same blend. Since the synthetic fibres/yarns are stronger than natural ones, it was observed that the strength of fresh yarn was slightly higher than recycled yarns in both counts.

Table 2 shows that twist per inch of recycled blended yarn was 7–8 (8 counts) and 9–10 (10 counts) which was less compared to control yarns of same counts, i.e. 8–9 and 10–11 for 8 and 10 count yarns respectively.

It was found that yarn strength and twist per inch of blended controlled yarns were higher as compared to recycled blended yarns of the same counts. The less number of twists in recycled yarns may be due to their uneven texture. More twist makes the yarn finer and provides even texture. The number of twists per inch was more in control yarns compared to recycled yarns. The texture of recycled yarn was rough; hence the number of twists made in an inch of yarn was less compared to control yarn. The results are in line with Nisha[4], who reported that with increased proportion of wool fibres, blended yarns resulted in lowering of twist per inch. Gupta and Saggu[5] observed that as yarn count increased, the number

Table 2. Physical properties of the selected yarns (8 and 10 counts)

	Recycled woollen blended yarn		Control yarn	
Properties	8s	10s	8s	10s
Yarn strength (kg)	0.756 ±	0.803 ±	0.786 ±	0.849 ±
Twist per inch	7–8	9–10	8–9	10–11

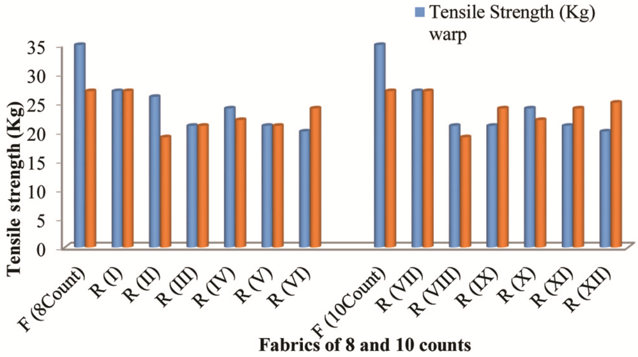

Figure 1. Tensile strength of 8 and 10 counts fresh and recycled fabrics. F, Fresh/control fabrics; R, Recycled fabrics.

of turns also increased. The twist per inch of 12 Nm yarn was found to be more compared to 8 Nm and 10 Nm yarns. According to Yuksekkaya *et al.*[6], the manufacture of recycled blended yarns using virgin cotton, recycled cotton, virgin polyester and recycled polyester fibres exhibited better properties in terms of unevenness, yarn imperfections and yarn quality index. Yarn tensile strength was low for recycled yarns and fabrics compared to virgin ones.

The selected yarns of 8s and 10s were used for weaving of fresh fabrics and recycled fabrics, which were tested for their mechanical properties, i.e. tensile strength, elongation and bending length. The constructed, fresh and recycled fabrics were compared and found suitable for making apparels.

The tensile strength of fresh (8 counts) warp direction was highest (Figure 1). The strength of control fabric woven using 8 count yarn was 35.48 × 27.72 kg warp- and weft-wise, which was higher than other fabrics.

The strength of recycled/shoddy fabrics I, II, III, IV, V and VI made using recycled woollen blended yarn of 8 counts was 27.30 × 27.60, 26.24 × 19.10, 21.46 × 21.21, 24.08 × 22.18, 21.46 × 21.21 and 20.50 × 24.96 kg respectively. All the developed fabrics are a blend of acrylic and polyester; the latter is for increasing the strength and for smooth texture of the fabrics.

The tensile strength of woven fabrics also revealed that the strength of control/fresh fabric woven using recycled woollen blended yarn of 10 counts was 35.90 × 27.92 kg warp- and weft-wise (Figure 1). As seen in Figure 1, tensile strength of fresh/control fabric was the highest. The fibre/yarn tensile strength and raw material are the major components that affect tensile strength of fabrics. The shoddy fabrics VII, VIII, IX, X, XI and XII made using woollen blended yarn of 10 counts had strength 27.20 × 27.02, 21.41 × 19.40, 21.41 × 24.10, 24.30 × 22.54, 21.41 × 24.10 and 20.80 × 25.40 kg respectively. It was observed that fabrics made using fresh fibres had a tendency to possess the highest tensile strength. This may be attributed to the higher tensile strength values of fresh woollen blend when compared to recycled woollen blend. The strength of recycled fabric was also similar to the fresh fabric because of being blended with polyester fibres at yarn manufacturing stage.

As seen in Figure 1, results of tensile strength of fabrics were similar to those of yarn. Higher tensile strength values were obtained for higher yarn strength values in fresh and recycled fabrics as expected. However, there was little variation in tensile strength in samples of the same blends of fresh and recycled fabrics.

The results highlight that the strength of fabrics woven with recycled blended yarn is less compared to control fabrics. The difference in strength of control and shoddy fabrics might be because the latter were woven with yarn made out of respun rags which had less tensile strength. The findings of the present study are supported by those

Table 3. Statistical analysis of tensile strength of fabrics

Woven fabrics	Tensile strength (kg) 8 counts		Tensile strength (kg) 10 counts	
	Warp Mean ± SE (m)	Weft Mean ± SE (m)	Warp Mean ± SE (m)	Weft Mean ± SE (m)
CD	5.75	–	5.86	4.42
F value	8.31 ±	2.60 ±	8.31 ±	4.32 ±
Significance	0.01* ±	0.05 ±	0.01* ±	0.01* ±
CV%	17.18	22.22	17.16	13.80

*Difference is significant at 0.05 level.

Table 4. Bending length of woven fabrics of 8 and 10 counts

Woven fabrics	Bending length (cm) 8 counts		Woven fabrics	Bending length (cm) 10 counts	
	Warp Mean ± SE (m)	Weft Mean ± SE (m)		Warp Mean ± SE (m)	Weft Mean ± SE (m)
Control	3.00 ± 0.05	4.62 ± 0.28	Control	3.06 ± 0.04	4.78 ± 0.24
I	4.50 ± 0.13	4.34 ± 0.05	VII	4.58 ± 0.12	4.38 ± 0.06
II	4.00 ± 0.12	3.46 ± 0.07	VIII	3.74 ± 0.10	3.50 ± 0.05
III	4.30 ± 0.18	4.10 ± 0.19	IX	4.46 ± 0.16	4.38 ± 0.20
IV	5.34 ± 0.10	4.38 ± 0.19	X	5.40 ± 0.10	4.42 ± 0.18
V	4.26 ± 0.18	4.10 ± 0.19	XI	4.46 ± 0.16	4.38 ± 0.20
VI	4.70 ± 0.10	4.20 ± 0.12	XII	4.74 ± 0.10	4.28 ± 0.10
CD	0.36	0.50	CD	0.33	0.47
F value	46.08 ±	5.25 ±	*F* value	53.08 ±	6.85 ±
Significance	0.01* ±	0.02* ±	Significance	0.01* ±	0.01* ±
CV%	6.55	9.23	CV%	5.80	8.43

*Difference is significant at 0.05 level.

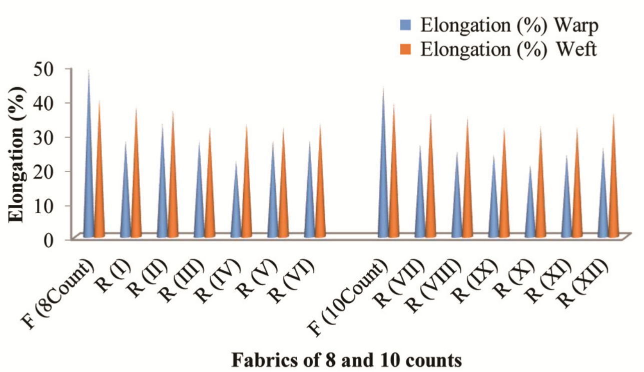

Figure 2. Elongation of 8 and 10 counts fresh and recycled fabrics. F, Fresh/control fabrics; R, Recycled fabrics.

of Yuksekkaya *et al.*[6], who produced fabrics from recycled fibres that are suitable for various applications, where the strength of the fabrics is less critical. Thus, recycled fibres seem most suitable for use in the manufacture of casual clothes such as t-shirts, sweatshirts and sleepwear, where unevenness, imperfections and handle properties are not of much importance.

The difference between values of fresh and recycled fabrics was significant at warp and weft directions except tensile strength of weft direction of 8 counts (Table 3). Statistical analysis showed that fresh and recycled fabrics blends with acrylic and polyester were significant at warp and weft directions, except for weft of 8 counts.

The bending length of all the fabrics was in the range 3.00–5.40, indicative of good or average bending length of all woven fabrics. Table 4 shows that the bending length of fresh/control fabrics woven using 8 counts yarn was 3.00–4.62 cm in the warp and weft directions.

The bending length of shoddy woven fabrics I, II, III, IV, V and VI made using recycled woollen blended yarn of 8 counts was 4.50×4.34, 4.00×3.46, 4.30×4.10, 5.34×4.38, 4.26×4.10 and 4.70×4.20 cm respectively. Bending length of both types of fabrics was similar ranging between 3 and 4.5 cm in the warp and weft directions. Bending length of woven fabrics was good; thus may be due to soft and smooth fabric texture produced with weave combination designs.

Statistically analysis of bending length values showed that there was no significant difference between all the woven fresh and recycled fabrics at warp and weft directions.

The percentage of elongation of fresh/control fabrics woven using 8 and 10 counts yarn was 49.42×40.82 and 44.62×39.00 respectively (Figure 2); it was higher than

Table 5. Statistical analysis of elongation of fabrics

Woven fabrics	Elongation (%) 8 counts Warp Mean ± SE (m)	Elongation (%) 8 counts Weft Mean ± SE (m)	Elongation (%) 10 counts Warp Mean ± SE (m)	Elongation (%) 10 counts Weft Mean ± SE (m)
CD	2.17	4.07	6.95	4.07
F value	154.92 ±	5.60 ±	154.92 ±	5.02 ±
Significance	0.01* ±	0.01* ±	0.01* ±	0.02* ±
CV%	5.20	8.62	18.71	8.99

*Difference is significant at 0.05 level.

recycled fabrics. The percentage of elongation of recycled fabrics I, II, III, IV, V and VI made using recycled woollen blended yarn of 8 counts was 28.70 × 38.30, 33.40 × 37.10, 28.80 × 32.80, 22.90 × 33.82, 28.80 × 32.80 and 28.02 × 33.02 respectively, which exhibited low elongation compared to fresh fabrics.

The percentage of elongation of all fabrics made using woollen blended yarn of 10 counts was 27.26 × 36.84, 25.56 × 35.22, 24.44 × 32.28, 21.20 × 32.58, 24.44 × 32.28 and 26.34 × 36.84 for fabrics VII, VIII, IX, X, XI and XII respectively.

The results highlighted that the percentage of elongation of fabrics woven with recycled blended yarn was less compared to control fabrics. The difference in elongation of control and shoddy/recycled fabrics might be because they were woven with yarn made out of respun rags, which have less tensile strength.

According to the statistical analysis of fabric, the elongation values of all the fabrics were significantly minor different from each other. A comparison between properties of fresh/control and recycled fabrics indicated that there was not much difference as indicated by *F*-value and CD calculated by one-way ANOVA test (Table 5). The similarities in properties of fresh/control and recycled fabrics may be due to same fibre composition. Hence, minor difference between values may be due to the use of fresh yarn in fresh/control fabrics and recycled yarn in recycled fabrics. The results of the study indicate that the fabric properties measured were mainly affected by yarn twist, yarn tensile strength and types of raw materials. The results of the present study are in agreement with those of Yuksekkaya *et al.*[6], who reported that yarns and fabrics produced from recycled fibres are suitable for various applications where the strength of yarns is less critical. Thus, recycled fibres seem most suitable for use in the manufacture of casual clothes such as t-shirts, sweatshirts and sleepwear, where unevenness, imperfections and handle properties are not of much importance.

In this study, the mechanical properties of yarns and fabrics produced from fresh and recycled wool, polyester and acrylic fibres have been compared. The properties considered for yarn were tensile strength and yarn twist per inch. Fabric properties were tensile strength, elongation and bending length. Generally yarn produced from recycled fibres exhibited better properties for use as recycled products, which require good mechanical properties. Yarns produced from recycled fibres exhibited better properties in terms of strength as well as twist per inch. It was found that the properties of recycled yarns were little less compared to yarns produced from fresh fibres. It was comparable to fresh yarns and can be used for making products where strength is required. Tensile strength of recycled fabric was slightly lower as compared to fabrics produced from fresh fabrics with the same blend ratio. All the recycled fabrics showed higher elongation at weft direction compared to fresh fabrics which had higher warp elongation. The results of this study indicate that yarns and fabrics produced from recycled fibres are suitable for applications where strength is required. Thus, recycled fibre blends with wool, acrylic and polyester may be suitable for winter apparels as well as household articles.

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