Chapter

Utilization of Cotton Spinning Mill Wastes in Yarn Production

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Abstract

Efficient use of natural resources and utilization of recoverable wastes are getting more and more important day by day since recovering wastes have both economic and environmental benefits. As the source material costs constitute the majority of the yarn production costs, decreasing raw material costs provide considerable advantages for spinners. From the point of textile manufacturing, various production wastes can be reused in textile industry. In each step, from ginning (for cotton fibers) to end product formation, recyclable/recoverable waste materials are generated. However, mainly polyester products are recycled (r-PET) and used again in textile industry by 100% or in blends with other man-made or natural fibers. Compared to research on r-PET, recovered cotton fibers inspired interest recently. The main objective of this study is to fill the gap in the literature via investigating the properties of the yarns produced with recovered cotton wastes, generated in different sources. For this purpose, spinning mill waste types were selected. In this experimental study, different waste types (card waste, blowroom waste, and fabric waste) and blending ratios were used. As a conclusion, the effect of waste type and blend ratio on the physical and mechanical properties of the yarns and the fabrics, produced with virgin and waste cotton fibers, were analyzed.

Keywords: waste, recovering, recycling, spinning mill, fiber, cotton

1. Introduction

Every being in this world has an expiration date, even the world itself possibly has one. This situation is the same for man-made products too. We produce them, use them, and try to find a way to get rid of them, when the time comes. One of the hardest questions of today comes to mind at this point: How will we manage the resultant waste of the products we created? Should we dump the waste to proper waste yards and reuse or recycle them? The answers to these questions are crucial. Scientists, governments, and local authorities work for finding answers to these questions. Wastes can be a problem for local authorities because of their environmental effects.

There are different categories of wastes. According to Australian Waste Report 2016, these categories are masonry materials (asphalt, bricks, rubble, etc.), metals (steel, aluminum, etc.), organics (food, garden organics, etc.), paper and cardboard (liquid paperboard, magazines, etc.), plastics (PET, HDPE, PP, etc.), glass, hazardous wastes, fly ash, and other wastes (including textiles and leather) [1]. Some of these waste types can be recycled and utilized as raw materials in same type of products they belong in or in different products.

Textile wastes can be divided into two main groups: production wastes and postproduction wastes. Production wastes are basically raw materials of each production step which cannot be put into end product due to different reasons. For yarn spinners, these wastes can occur during cleaning of the fibers or combing out short-staple fibers from the long ones in combing machine, etc. These clean/unclean wastes in fiber form or not can be reused. After spinning mill, there are wastes in yarn and fabric forms, and they need recycling to be put again in production. Postproduction wastes are generally worn out cloths, which can be recycled and may be used again in textiles or utilized in other products.

Textiles include different raw material (fiber) types. Fibers used in textiles are categorized into two main groups, which are natural and man-made fibers. Most known examples for natural fibers are cotton (seed fibers), wool, silk (animal fibers), flax (bast fibers), sisal (leaf fibers), and asbestos (mineral fibers). On the other hand, polyester, nylon, acrylic (which are synthetic fibers), modal, viscose rayon, and acetate rayon (which are regenerated fibers) are some of the examples for man-made fibers [2]. Thereby, textile wastes have a great variety of raw material sources. These wastes can be recycled or reused in different products. In 2017, global fiber production exceeded 100 million mt. Polyester has around 51% of total global fiber production. The second most important fiber is cotton, and it has approximately 25% of total global fiber production [3].

Textile wastes can be recycled/reused in textiles or other products. Other product wastes can also be utilized in textile production. One of the most known examples for this is PET bottles. PET bottles are collected, are recycled, and can be used in textile products as "r-PET fiber." r-PET fibers can be used in yarn production, as 100% or in blends, thereby in most of the textile structures. There are various studies about this topic. These studies cover spinning of the fiber, properties of the fiber [4], properties of yarn, and fabric produced from this fiber and all [5]. Some of the researches are focused on using textile wastes in different products. Mishra et al. used textile wastes to produce composites and tested the properties of these composites [6]. Briga-Sa, Binici, and El Wazna used textile wastes as insulation materials, and Briga-Sa indicated that they got results similar to polystyrene (XPS) and mineral wool [7–9]. Shukla used PET fiber wastes to synthesize new chemicals which can be used in different fields [10]. These examples show that textiles are generally sustainable materials. There are too many studies dedicated on this topic.

Liquid waste and solid waste are generated during the production of textiles. Especially agriculture of cotton fiber, which is the subject of this study, and the evaluation of the solid wastes that occur during yarn spinning are important for sustainability and environment. These topics are really important for the future, considering the increasing world population and decreasing agricultural areas. Moreover, large amounts of water are consumed; pesticides and synthetic fertilizers are used during cotton growing. Especially pesticides have negative effects on human health. The recycling/reusing of wastes occurring at every stage of textile production will be positive in terms of reducing the environmental effects putting them again in the production chain. Consumers are also becoming more conscious about these effects and they seek environmentally friendly "green products" [11]. This should be considered by the producers.

Due to increasing fiber production, the amount of pre-consumer and postconsumer textile wastes is increasing. According to a study Pinheiro and de Francisco conducted with Brazilian clothing manufacturers, 167,850 kg of cotton was consumed with these manufacturers, and 19,086 kg of cotton waste occurred in

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their productions. This means 11% of the raw material was left out as waste [12]. Moreover, as the amount of textile solid waste increases, the evaluation of these wastes becomes more important. Therefore, the terms of sustainability and circular economy issues come to the forefront in textile industry. This chapter is focused on spinning mill wastes of textile wastes. Information about how textile wastes occur in spinning mills and utilization of them in textiles are given. For this reason, informations about spinning mill and wastes occurring in spinning mill were given, initially.

1.1 Short-staple yarn spinning

Spinning is defined by Barker as the "*art of throwing a number of more or less short fibres together in such a way that, being drawn out to form a comparatively fine filament*" [13]. In this process, one of the main defining parameter is fiber length. According to fiber length, machinery and their adjustments that should be used are determined. In textile yarn manufacturing, two main systems are used depending on fiber length: short-staple and long-staple spinning systems. In principle, fibers up to 60 mm in length are spun in short-staple spinning systems, and fibers with lengths over 60 mm are spun in long-staple systems. Short-staple fibers are generally processed dry using mechanical means, and the spinning systems used for this types of fibers are also known as cotton spinning system [14].

From the field, seed cotton moves to gins for separation of lint and seed. This is the first step in which cotton wastes occurred. Cotton gin wastes consist of sticks, leaves, burs, soil particles, mote, cotton lint, and other plant materials [15]. These wastes can be used in different areas such as chemical industry (e.g., soaps), livestock industry (e.g., animal feed), or food industry (e.g., cotton seed oil).

After harvest and ginning, cotton fibers are compressed and bales are formed. For this reason, the first step in a cotton spinning mill is opening. This process is needed in order to clean effectively and form slivers in which individual fibers are oriented very closely to sliver axis [16]. Most of the opening and cleaning is carried out in blowroom machinery. However, card has an important role in opening and cleaning. Most of spinning mill wastes occur in these machinery.

Parallelization is carried out subsequent to opening and cleaning processes. It is really important to force fibers to place as parallel to each other as possible in sliver to spin a good quality yarn. Machine mainly responsible for this process is draw frame which also takes care of attenuation and doubling of slivers. Fibrous waste amount of these machines is lower compared to the rest of the spinning mill machinery.

To produce some cotton end products especially in which fine yarns are used, yarns with better properties are needed. One of the ways to do so is to remove some fibers that are much shorter than the mean of the distribution from slivers [16]. This process is carried out with combing machine. In **Figure 1**, spinning machinery line with combing machine is given. Cotton fibers longer than 27 mm are generally used after combing up to 13% which is sufficient for good quality yarns [16]. This means waste ratio of this process is high.

During roving and spinning (for ring spinning), some fibers cannot enter yarn or roving body, and fiber fly is formed. These fibers are sucked by pneumatic systems that are placed after delivery rollers, and they are collected in the machine. Moreover, if end breaks happen in yarn or roving, the same system collects flowing fibers after leaving delivery rollers till operator's intervention. In open-end rotor spinning systems wastes can occur in opening rollers which also are responsible for cleaning.

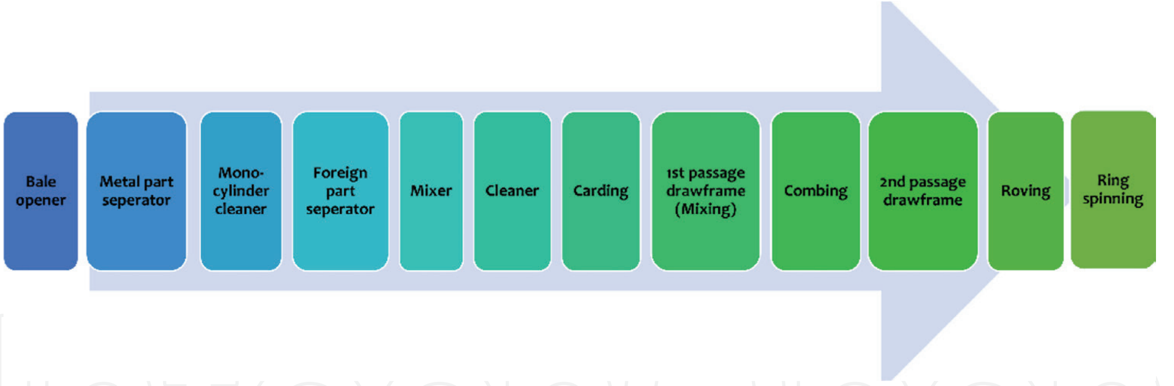

Figure 1.
Opening and cleaning lines of combed ring spinning [17, 18].

1.2 Cotton wastes in spinning mill

Klein classified cotton fibers used in short-staple spinning as virgin fiber (from ginning mill), clean waste, comber waste, recycled fibers from dirty waste, and fibers torn out of hard waste (roving, yarn, and twisted threads) [19]. Spinning wastes and their sources are given in **Figure 2**.

Broken ends of sliver, lap, web, and filter strippings from draw frame, roving frame, ring spinning frame, and rotor spinning frame are known as clean waste, having more than 95% of good fiber. Comber and roving wastes' good fiber ratio is around 95–97%. Wastes generated in blowroom machines, and cards are dirty wastes with 35–55% good fiber ratio. Besides, another dirty waste, flat and filter stripping waste, has a higher amount of good fiber (65–80%). As the waste fibers are processed in different number of machines and therefore stressed fibers, their good fiber content is less than virgin fibers. For this reason, spinners prefer to feed the waste fibers into normal spinning process, in a controlled manner, with a constant percentage in order to avoid quality variations. Generally, wastes arising in the mills can be returned to the same blend from which they arose; comber wastes are mostly used in rotor spinning. In carded ring-spun yarn and fine rotor-spun yarn production, waste fibers can be used, up to 5%, but for combed yarns, waste fiber ratio can be lower, up to 2.5%. Higher waste fiber amounts can be used for medium and coarser rotor yarns, about 10 and 20%, respectively.

Figure 2.
Spinning mill wastes in different sources.

According to Klein, waste generation in spinning mills of industrialized countries differs from machine to machine. The waste mostly occurs in comb machine, as one of its primary functions is to remove short fibers which are called comber wastes. Lowest waste creating machine in the spinning mill is draw frame. If the spinner is producing carded yarns, blowroom is responsible for the most waste generation. However, in blowroom machinery and card, shorter fibers have the highest ratio in the resultant waste despite ring spinning frame. In ring spinning frame and comber, waste consist of longer fibers (up to 1 1/2″) in comparison with card and blowroom machinery [20].

As the raw material costs constitute the majority of yarn production costs, spinners prefer to use waste fibers in the blends. In addition to saving raw material costs and the requirement for efficient use of limited raw material resources, the possibility of using higher degree of cleaning in the blowroom machines is the other advantage. On average, about 6–8% primary waste which is composed of 50% good fiber can be expected. About 90% of the good fiber elimination can be recovered as secondary raw material that is still containing 6% trash.

Many researches focused on cotton spinning wastes. Wulfhorst concluded that these secondary raw materials can be blended with raw materials with a percentage up to 20%, without noticeable changes in yarn quality [21].

Duru and Babaarslan have determined an optimum opening roller speed for spinning different types of 60/40 polyester/waste blended rotor yarns. Waste fibers were obtained from cotton noil, recycled fibers, flat waste, etc. and were blended and processed on the traditional short-staple (carding) system. They have found that yarn strength, unevenness, and hairiness values decreased with the increase of the opening roller speed, and the optimum opening roller speed was 7000 rpm for both yarn properties and cleaning effects [22].

The effect of some rotor spinning parameters, such as rotor diameter, rotor speed, separator angle, navel type, opening roller speed, and yarn linear density on the level of yarn hairiness of the rotor-spun yarn produced from ginning wastes in different waste proportions, was investigated by Hasani et al. by the Taguchi method. They have found that, for 35/65 cotton waste-spun yarns, rotor diameter was the most effective factor, followed by yarn linear density, separator angle, opener speed, navel type, and rotor speed factors, respectively. Yarn linear density was the strongest effect for 50/50 cotton waste-spun yarns, and it was followed by rotor diameter, rotor speed, opener speed, navel type, and separator angle factors. Rotor speed and opener speed were found the least effective factors of all, for 65/35 cotton waste-spun yarns [23]. According to their following research, the rotor diameter, yarn linear density, and the navel type had the largest, and the opening roller speed had the lowest effect on yarn hairiness, for all waste ratios. Furthermore, they have found that yarns produced with higher waste proportions had higher hairiness values [24].

Khan and Rahman have focused on the effects of rotor spinning parameters too. They have studied the effects of rotor speed, combing-roll speed, and type of recycled waste on rotor yarn quality and end breakage, using response surface methodology. They have collected spinning wastes from different positions of ring spinning process (flat strips, noil, filter waste, and Pneumafil) and used after recycling, except Pneumafil. They have reported that yarn strength, elongation, imperfections, and end breakage rate can be improved by using Pneumafil waste, mostly in the range of 5–25%. The negative impacts of rotor speed on yarn imperfections and end breakage can be minimized also. In their study, rotor and combing-roll speed of 85,000 rpm gave better results in terms of yarn strength and elongation; on the other hand, the lowest end breakage rates were found at lower speeds [25].

Khan et al. have also focused on predicting the unevenness, imperfections, strength, and elongation properties of cotton/waste blended rotor yarn, using

Taguchi OA experimental design. They have used blend ratios, blending technique, cylinder speed, and rotor speed as predictors. They have collected flat strips from carding machines and recycled them. Besides, comber noils, untwisted roving wastes, and Pneumafil wastes were directly used. They have produced virgin cotton/spinning waste blended yarns with two different levels of blend proportion (17/83 and 33/67) for both blowroom blending and draw frame blending. Their model showed that blend ratio and rotor speed are the most influencing factors for yarn quality. Reducing rotor speed improved the yarn evenness, imperfections, and strength. Yarn strength was found lower with draw frame blending, but on the other hand with this blending type, high portion waste containing yarns' evenness, imperfection, and elongation values are better than blowroom blending [26].

Halimi et al. investigated the effect of waste ratio (0, 12.5, 25, 37.5, 50, 62.5, 75, and 100%) and spinning parameters (rotor type, rotor speed, and opening roller speed) on the rotor yarn quality. Cotton wastes were collected from opening-cleaning machines and cards processed to reduce impurities. Greek cotton was chosen due to the suitable fiber length for blending with recovered fibers. They have reported that yarn appearance, level of irregularity, and the yarn uniformity did not affect up to 25% waste ratio [17, 18].

Celep et al. investigated the thermal comfort properties of the single jersey fabrics produced from virgin/recycled cotton fiber-blended open-end rotor yarns (100/0, 50/50, and 0/100). Recycled cotton fibers were obtained from fabric scraps from garment industry. They have found that fabrics containing recycled cotton fibers show higher thermal resistance and lower thermal conductivity, thermal absorptivity, and air permeability and give a warmer feeling at first touch [27].

Recycled denim fabrics by using recycled cotton fibers (varying from 30 to 85% blend ratio), recycled PES fibers, Tencel fibers, and virgin cotton fibers were produced. They have found that recycled fiber-blended yarns have higher unevenness, IPI faults, and hairiness comparing to the standard yarns, resulting with noticeable nubs in fabric surface. This case did not affect fabrics' physical and mechanical properties significantly but provides better abrasion resistance contrary to expectations from recycled products [28].

Yılmaz et al. have focused on the effects of different waste cotton fiber types and the amount of waste in the blends (varying from 5 to 40%), on the quality of conventional ring and OE-rotor yarns. They have used preparation process wastes (blowroom and carding) and Pneumafil wastes (sucked on the draw frame, roving frame, and conventional ring spinning machines). They have found both for conventional ring-spun and OE-rotor yarns that the blends containing pneumafil wastes resulted with better yarn properties, while the blends with blowroom and flat wastes caused worse yarn qualities. In general, flat waste fiber blends have higher neps and hairiness values. They have concluded that when the waste percentage was increased from 5 to 40%, yarn irregularity values increased up to 37 and 16%, yarn hairiness increased by about 21–22%, yarn tenacity values decreased by 22, and 52%, breaking elongation decreased by 7 and 38%, for ring-spun and rotor yarns, respectively. As expected, with the usage of waste fiber, the most deteriorated yarn properties were yarn unevenness in conventional ring-spun yarns and tensile properties in rotor yarns. Their findings showed that the effect of waste fiber usage on knitted fabrics' pilling behavior was significant and Pneumafil fiber blends increased the pilling resistance, while for other waste fiber blends, on the contrary [29].

Béchir et al. evaluated the effect of recycled fiber ratio and number of recycling passages on the yarn quality and predicted the quality of the blend using a mathematical approach. They have concluded that recycling process of cotton waste with four passages gave an optimal global quality of fibers. Unevenness and IPI values of blended yarns increased with the increasing of recycled fiber ratio in the yarn [30].

Demiroz Gun et al. studied the dimensional and physical properties of the socks made from the blend of reclaimed fiber and polyester fiber. As a result of the study, they reported that reclaimed fiber can be used for production of socks, when the blend of virgin polyester fiber and reclaimed fiber are used, and thus acceptable quality can be obtained [31].

Yuksekkaya et al. used "yarn quality index" value, which was defined by Yunus and Rahman (as Yarn Quality Index = (Strength × Elongation)/ Evenness), for evaluating yarn quality in their study [32, 33]. It can be said that the most important parameter in order to evaluate yarn spinnability is the yarn tensile strength. They reported that generally, yarns produced from recycled fibers displayed better properties in terms of unevenness, yarn imperfections, and yarn quality index value. On the other hand, they found that yarn tensile strength and fabric burst strength were lower for recycled yarns and fabrics when compared to virgin ones [32].

2. Material and methods

The main objective of this study is filling the gap in the literature via investigating the properties of the yarns produced with cotton wastes, generated in different sources. For this purpose, different waste types (card waste, blowroom waste, sliver waste, and recycled cotton fiber from ecru fabric waste) and waste ratios (10/90, 30/70, and 50/50) were used in rotor spinning. As a pre-treatment and recycling process, all waste types were processes in Micro Dust and Trash Analyzer (MDTA) in two passages. Simultaneously, trash and fiber content of these wastes were analyzed, and the fiber length specifications of wastes after recycling process were evaluated by length control tester (Textechno). Length control tester is a mobile device for use in the spinning mill, developed for the measurement of fiber length parameters on slivers or cotton in tuft form. The test results of length control tester give information about the mechanical stresses which the fibers undergo in the manufacturing process and optimum settings of card, draw frame, or combing machines [34]. Besides, fiber contents of the wastes were analyzed with MDTA, and test results are given in **Table 1**. Trash analysis of the virgin cotton was performed from sliver form, resulting with high ratio of fiber content. Subsequently, wastes were blended with virgin cotton fibers (in sliver form) with the same machine. Then, Ne 20/1 open-end yarns were spun by using these slivers on Rieter open-end machine (R40). Single jersey fabrics were knitted by using Mesdan Lab Knitter with the same tightness factors under constant machine settings.

Waste type	Fiber content (%)	2,5% SL* (HVI) (upper length) (mm)	50% SL (mm)	ML* (AFIS) (LCT length) (mm)	Fiber hooks (%)	SFL* (mm)	SFA* (%)	SFC* (AFIS short fiber amount) (%)	Staple gradient (HVI uniformity ratio)
Blowroom	45.74	25.27	9.24	15.62	5.3	7.26	56.4	38.0	38.4
Card	82.44	21.69	6.71	7.79	1.2	2.81	78.0	76.6	33.0
Sliver	82.11	27.63	11.62	11.04	0.4	11.04	44.5	15.0	42.0
Fabric	80.89	22.64	8.46	13.36	8.4	6.07	57.2	47.6	39.6
Virgin cotton	99.41	27.67	12.50	20.59	4.8	10.38	42.5	17.4	42.5

**is corresponding to the test result given in brackets.*

Table 1.
Fiber specifications.

The standards of yarn and fabric tests applied were given below:

- Bursting strength (EC 37 hydraulic bursting strength tester) TS 393 EN ISO 13938-1
- Air permeability (Textest FX 3300) TS 391 EN-ISO 9237, ASTM D737
- Pilling test (ICI Pilling Box-7000 tours) TS EN ISO 12945-1
- Fabric thickness (SDL Digital Thickness Gauge) TS 7128 EN ISO 5084
- Yarn strength test (Lloyd yarn strength tester) TS 245 EN ISO 262, ASTM D 2256
- Yarn evenness test (Uster Tester 5) ISO 16549

The effect of waste type and blend ratio on the physical and mechanical properties of the yarns and the fabrics, produced with virgin/waste cotton fibers, were statistically analyzed by using SPSS.

3. Results and discussions

According to the results given in **Table 1**, the sliver waste and virgin cotton fibers have similar fiber specifications, because of being a clean waste as mentioned previously.

Physical and mechanical properties of the yarns were tested, and the test results were given in **Table 2**. In addition, the fabric thickness, bursting strength, air permeability, and pilling values of the fabrics were tested, and the test results were

Waste type	Waste/virgin cotton	Uster (CV%)	Thin places (−50%)	Thick places (+50%)	Nep values (+280%)	Yarn hairiness (H)
Blowroom	10/90	16.88	9.17	106.67	105.00	5.53
	30/70	17.95	361.67	245.83	412.50	5.76
	50/50	19.47	18.33	385.00	383.33	6.15
Card	10/90	16.53	5.83	50.00	23.33	5.84
	30/70	16.64	10.00	75.00	59.17	6.37
	50/50	15.48	4.17	78.33	62.50	6.82
Sliver	10/90	15.81	16.67	22.50	8.33	5.24
	30/70	15.68	28.33	27.50	11.67	5.14
	50/50	16.94	29.17	26.67	6.67	5.05
Fabric	10/90	16.30	5.00	75.83	40.00	5.58
	30/70	16.27	1828.33	186.67	1077.50	5.86
	50/50	16.26	52.50	209.17	125.00	6.04
Virgin cotton	0/100	15.26	8.00	26.00	6.00	5.32

Table 2.
Yarn test results.

Waste type	Waste/virgin cotton	Fabric thickness (mm)	Air permeability (l/m^2/s)	*Pilling (1–5)
Blowroom	10/90	0.78	1440	2–3
	30/70	0.75	1274.8	3–4
	50/50	0.78	1282	3
Card	10/90	0.78	1444	5
	30/70	0.76	1412	5
	50/50	0.79	1256	5
Sliver	10/90	0.76	1758	4
	30/70	0.75	1830	4–5
	50/50	0.73	2052	4
Fabric	10/90	0.76	1552	4
	30/70	0.82	1410	3–4
	50/50	0.78	1534	3
Virgin cotton	0/100	0.67	2786	4–5

**1, worst–5, best.*

Table 3.
Fabric test results.

given in **Table 3**. For better understanding and evaluation, yarn tenacity and bursting strength values of different samples are given in **Figure 3**, respectively.

The effects of waste amount and waste type on yarn and fabric properties were statistically analyzed (**Table 4**). The effects of waste amount on yarn and fabric properties were found statistically significant, except yarn unevenness values. According to the Student-Newman-Keuls test, the number of thick places and nep values of the yarns produced with blowroom wastes were statistically significantly highest, of all. In terms of yarn hairiness, the highest values belong to the yarns produced with card waste, for all blend ratios. Card waste has the highest short fiber amount, resulting with the yarns' hairiness. For higher waste ratios (50/50), clean sliver waste containing yarns show better yarn tenacity, close to 100% virgin cotton.

One of the main factors affecting measured fabric properties is yarn hairiness. Yarn hairiness increases, and bursting strength decrease with the increase of waste ratio, except when the waste type is sliver. Sliver waste/virgin cotton-blended yarns have the lowest yarn hairiness values and highest bursting strength, even better than virgin cotton, because of better fiber specifications.

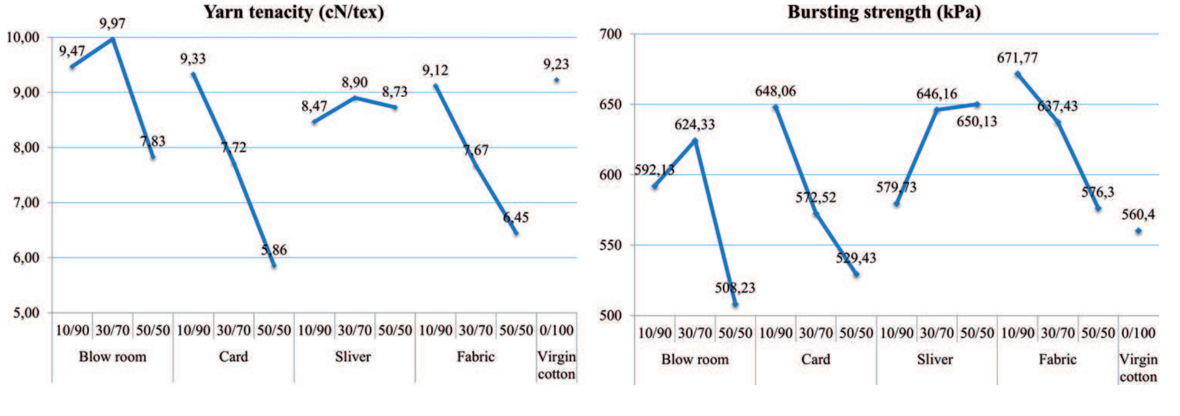

Figure 3.
Yarn tenacity and bursting strength values of different samples.

	Significance (p)			Significance (p)			
	Waste/virgin cotton ratio			Cotton waste type			
	10/90	30/70	50/50	Blowroom	Card	Sliver	Fabric
Yarn evenness (CV%)	0.541	0.541	0.541	0.160	0.478	0.806	0.998
Thin (−50%)	0.008*	0.008*	0.008*	0.117	0.460	0.838	0.086
Thick places (+50%)	0.000*	0.000*	0.000*	0.001*	0.087	0.700	0.005*
Nep values (+280%)	0.000*	0.000*	0.000*	0.034*	0.011*	0.780	0.120
Yarn hairiness (H)	0.000*	0.000*	0.000*	0.000*	0.000*	0.001*	0.001*
Yarn tenacity (cN/tex)	0.874	0.020*	0.002*	0.028*	0.000*	0.788	0.009*
Elongation at break (%)	0.013*	0.001*	0.321	0.026*	0.225	0.331	0.042*
Fabric thickness (mm)	0.000*	0.000*	0.000*	0.063	0.383	0.488	0.039*
Bursting strength (kPa)	0.014*	0.237	0.030*	0.035*	0.021*	0.194	0.029*
Air permeability ($l/m^2/s$)	0.000*	0.000*	0.000*	0.014*	0.200	0.001*	0.472

*Significant for $\alpha = 0.05$.

Table 4.
The results of variance analysis of the effects of different waste types and waste ratio on yarn and fabric properties.

Fabric pilling values show that blowroom and fabric wastes containing fabrics have more pilling. Fabrics produced with card waste have a lower pilling degree and higher short fiber content but lower short fiber length. Probably, short fibers are too short to compose a pill in card waste.

4. Conclusions

In this study, the waste of yarn spinning mill and recycled cotton fiber from fabric waste were blended different blending ratios (10, 30, and 50%) with virgin cotton fiber. Ne 20/1 cotton open-end yarns were produced from these blends. The yarn physical properties of these yarns were tested. The effects of waste ratio and waste type on yarn properties were investigated. According to the test results, the dirty waste (blowroom waste and card waste) used in this study showed a different tendency from the clean waste (sliver waste and fabric waste fiber). The blowroom and card waste occurred during the cleaning of the fibers. They contain too much short fibers and vegetable matters. Especially, card waste contains the shortest fibers used in this study. For this reason, the yarn hairiness values are greater than the others. Besides, the yarn tenacity containing 50% card waste was lower than the others. However, in case of the use of blowroom waste, the number of thick places and the number of nep were found greater than the others. On the other hand, the content of the blowroom waste in the yarns has not influenced the yarn properties except for thick places and nep values up to ratio of 30%. When fibers recycled from the fabric have been used, it has been seen that the results are similar to those obtained when using the blowroom waste.

Fabric thickness, bursting strength, air permeability, and pilling values of fabrics were tested. When the results are examined, the use of blowroom waste up to 30% in the fabric has not affected the bursting strength adversely. However, when the ratio increased to 50%, the bursting strength decreased. When card waste was used, the values of bursting strength decreased as the waste rate increased. For the bursting strength values, it can be said that it is possible to blend up to 50% of the cotton fibers recycled from fabrics. Depending on the yarn hairiness values, the air permeability values of fabrics decreased as the ratio of waste fibers increased, except for the sliver waste.

Today, the recovery of waste and its use in specific proportions within the yarn blend is increasing day by day. According to the results of this study, it can be said that the blowroom waste and the fiber recycled from the fabric gave similar results and that the use of the wastes up to 50% did not affect the yarn and fabric properties adversely. It caused greater results in terms of only thick places and nep values than the other ones. On the other hand, card waste can be used in yarn blends up to 30%, depending on the high short fiber content they contain. Sliver wastes showed similar results compared to 100% virgin cotton fibers, as they are already clean wastes.

According to test results of the pilling values of fabrics, the best values were obtained when the card waste is used. On the other hand, the card waste has the highest short fibers content. It is thought that the short fibers are easily removed from the fabric surface after forming the pills in the fabric by itself and thus do not cause deterioration in appearance.

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Photos of wastes and machines in **Figure 2** were taken by the authors in a Turkish spinning mill.

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