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EFFICIENT UTILIZATION OF COTTON ROVING WASTE AS A SECONDARY RAW MATERIAL

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Abstract: Cotton roving waste is a pre-consumer fibrous waste generated during roving preparation, machine stoppages, roving breakages and material handling in cotton spinning mills. Because this waste contains reusable cotton fibers, its recovery and reintegration into textile production can reduce the consumption of virgin raw materials and improve material efficiency. Previous investigations have shown that roving waste may represent approximately 3.5–5.2% of production volume in spinning mills, with mechanical inefficiencies, operator handling errors and raw-material variability identified as the principal causes of waste generation [1]. Other research has reported that roving waste can contain a high proportion of usable fibers and can therefore be considered a valuable secondary raw material [2]. This paper analyzes the technological potential of cotton roving waste as a secondary raw material, focusing on mechanical recycling, fiber recovery, blending and subsequent spinning. The results of previous experimental studies indicate that an improved mechanical processing machine achieved a fiber recovery rate of up to 80%, while yarn containing up to 20% recycled roving fibers demonstrated acceptable tensile strength and evenness for medium-count yarns [3]. Research on other cotton waste streams also confirms that controlled mechanical processing and appropriate blending ratios are important for maintaining yarn quality [5–10]. The analysis demonstrates that efficient utilization of roving waste requires controlled opening and cleaning, preservation of useful fiber length and appropriate blending with virgin cotton.

Keywords: cotton roving waste, secondary raw material, mechanical recycling, fiber recovery, recycled cotton, roving recycling, cotton spinning, yarn quality, waste utilization.

Introduction. The production of cotton yarn involves several technological operations, including opening and cleaning, carding, drawing, roving and spinning. Fibrous waste is generated at different stages of this production chain. Among these waste streams, roving waste is directly associated with the roving and subsequent spinning processes and consists mainly of broken rovings, material losses and fibers that do not enter the intended product.

The utilization of cotton roving waste is important because the material still contains potentially usable cotton fibers. Alikhonov reported that roving waste represents a valuable secondary raw material that can be returned to the production chain through appropriate recycling and blending strategies [1].

A six-month waste audit conducted at three large-scale spinning mills by Alikhonov and Bobojanov showed that roving waste accounted for approximately 3.5–5.2% of total production volume. The main identified causes were mechanical inefficiencies (42%), operator handling errors (31%) and raw-material variability (27%) [2].



Figure 1. Roving waste.

These data indicate that the problem of roving waste has two interconnected aspects. The first is the reduction of waste generation during production, while the second is the recovery and reuse of the waste that is inevitably generated.

From the resource-efficiency perspective, the second aspect is particularly important because the discarded material still contains cotton fibers that have already passed through several stages of processing. Returning these fibers to production can therefore reduce the requirement for additional virgin cotton.

The quality of recovered fibers, however, is a major limitation of mechanical recycling. During opening, tearing and cleaning, excessive mechanical action may shorten fibers and increase the proportion of short fibers. Research on cotton textile waste has demonstrated that the characteristics of the original waste and the applied mechanical treatment significantly influence the quality of the recovered fibers [5].

Therefore, the objective of this paper is to analyze the efficient utilization of cotton roving waste as a secondary raw material, with particular attention to mechanical processing, fiber recovery and blending with virgin cotton.

Materials and methods. The study was conducted using a comparative literature-analysis approach. Published research concerning cotton roving waste, cotton spinning waste, mechanical recycling and the use of recovered cotton fibers in yarn production was analyzed.

The literature was divided into three groups:

1. studies specifically dealing with cotton roving waste;
2. studies dealing with cotton spinning waste and mechanical fiber recovery;
3. studies investigating the spinning performance of recycled cotton fibers.

Particular attention was given to publications reporting quantitative information such as:

- percentage of roving waste generated;
- causes of waste formation;
- fiber recovery rate;
- proportion of recycled fibers in yarn;
- yarn tensile strength and evenness;
- fiber length and short-fiber content;

- influence of mechanical-processing parameters.

Alikhonov's studies were used as direct sources for information concerning roving waste generation, recycling and the economic aspects of its utilization [1–4]. Experimental data from other researchers were used only for the waste materials and processing conditions actually investigated in their respective studies.

This approach was used to avoid transferring experimental results obtained from fabric, yarn or blowroom waste directly to roving waste without appropriate evidence.

Results and discussion. The available literature shows that roving waste is generated mainly as a result of roving breakages, machine stoppages, material handling and other operational losses.

According to the six-month industrial audit reported by Alikhonov and Bobojanov, roving waste represented 3.5–5.2% of total production volume in the investigated spinning mills [2]. The contribution of mechanical inefficiencies was 42%, operator handling errors accounted for 31%, and raw-material variability accounted for 27% of the identified causes [2].

These results demonstrate that not all roving waste is generated because of the intrinsic properties of cotton. A considerable part of the waste is associated with machine operation and production organization.

The same study reported that implementation of an integrated waste-management protocol combining machine calibration, operator training and in-process recycling resulted in a 47% reduction in waste generation. The study also projected annual cost savings of US$18.50 per metric ton of production [2].

Thus, the efficient utilization of roving waste should begin not only with recycling but also with reducing unnecessary waste generation.

Roving waste differs from highly contaminated textile waste because it originates relatively close to the final yarn-production stage. Alikhonov described cotton roving waste as a secondary raw material that can be reintegrated into spinning after suitable preparation [1].

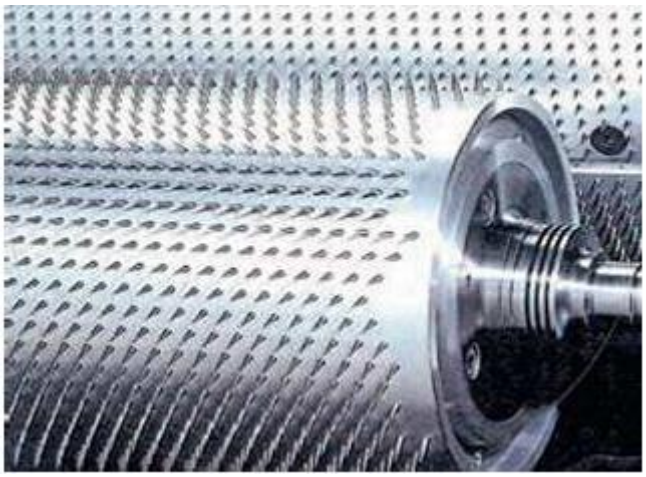


Figure 2. Mechanical beater.

Bedez Ute et al. reported that clean wastes originating from drawing, roving, ring spinning and rotor spinning contain more than 95% good fiber, while comber and roving wastes may contain approximately 95–97% good fiber [5]. In contrast, blowroom and card wastes were reported to contain approximately 35–55% good fiber [5].

This difference has direct technological significance. If a waste stream contains a high proportion of useful fibers, intensive cleaning may not be necessary. Excessive mechanical treatment can instead cause unnecessary fiber damage.

Consequently, roving waste should be processed using a technology that provides sufficient opening and separation while avoiding excessive mechanical action.

Mechanical recycling is one of the principal approaches for recovering fibers from cotton waste. The basic objective is to convert the waste into a sufficiently open fibrous form suitable for subsequent processing.

Alikhonov's study on cost reduction through efficient roving waste recycling investigated an improved mechanical processing machine. The machine incorporated a controlled feeding system, optimized opening elements, adjustable drafting units and a mechanical design intended to reduce frictional losses [3]. The investigated process parameters included drafting ratio, roller speed, feed rate and cleaning intensity [3].

The study reported a fiber recovery rate of up to 80% using the improved roving-waste processing machine [3]. Controlled feeding and optimized opening were reported to reduce fiber damage during processing [3].

This result is particularly relevant to the use of roving waste as a secondary raw material because the recovery rate indicates the proportion of material that can be returned to further processing after mechanical treatment.

However, recovery rate alone is insufficient for evaluating the effectiveness of recycling. The quality of the recovered fibers must also be considered.

The mechanical treatment of cotton waste involves forces that separate fiber bundles and remove unwanted material. If the treatment is excessively intensive, the fibers may be shortened.

Ütebay et al. investigated the effect of cotton textile-waste properties on recycled-fiber quality. Their results demonstrated that recycled cotton quality was affected by fabric structure and finishing treatments. They also found that recycled fibers obtained from dyed fabric wastes generally had lower quality values than fibers obtained from selected greige cotton wastes [6].

Although this investigation was conducted on cotton textile waste in fabric form rather than roving waste, it confirms an important general principle: the characteristics of the initial waste and the recycling conditions must be considered together.

A 2024 experimental study on mechanical preparation of colored denim yarn waste compared two opener designs. The seven-roller OP2 opener provided better results than the two-roller OP1 opener for process yield, fiber length, fiber strength and fiber quality index [7]. The study concluded that process design had a more significant effect on overall fiber quality than the number of passages [7].

These findings support the need for equipment specifically adapted to the characteristics of the material being recycled.

One of the practical ways of utilizing recovered cotton fibers is to blend them with virgin cotton before spinning.

Alikhonov's experimental study investigated recycled roving waste blended with virgin cotton at 5%, 10%, 20% and 30% levels [3]. The resulting yarn samples were evaluated in terms of fiber recovery, tensile strength, yarn evenness and raw-material cost savings [3].

The reported results showed that yarns containing up to 20% recycled roving waste demonstrated acceptable tensile strength and evenness for medium-count yarns. At higher blending ratios, a slight deterioration in quality was observed, although the yarn remained suitable for non-critical applications [3].

The same study reported that the use of 20% recycled fibers reduced cotton consumption and provided substantial raw-material savings [3].

These results indicate that the optimum utilization of roving waste does not necessarily require using 100% recovered fibers. Controlled blending can provide a practical balance between resource recovery and yarn quality.

Research conducted on other types of cotton spinning waste provides additional evidence concerning the relationship between recycled-fiber content and yarn quality.

Halimi et al. investigated cotton waste and rotor-spinning parameters and established statistical models for predicting yarn quality. Their results showed that rotor diameter, rotor form and rotor speed had an influence on yarn quality comparable to the waste proportion [8]. Under optimum spinning conditions, secondary raw material could be incorporated at 15–25% without hardly noticeable changes in quality [8].

The same study reported that increasing the waste proportion from 0 to 100% reduced the Total Quality Index by 36.3%, whereas increasing the waste proportion from 0 to 25% reduced it by only 6.5% [8]. The authors associated the deterioration at high waste proportions with higher short-fiber content and lower fiber maturity [8].

These findings support the experimental result obtained by Alikhonov that moderate blending of recycled roving fibers can provide a better balance between material recovery and yarn quality.

Optimization of the recycling process. Wanassi et al. studied the optimization of the recycling process for waste cotton yarn. Their experimental design considered the cut length and number of recycling passages as factors affecting the quality of reclaimed fibers [9].

The optimized reclaimed fibers reported in the study had a mean fiber length of 18 mm, Short Fiber Content of 26%, Upper Quartile Length of 23.9 mm, and a weight yield of 61.20% [9].

The reclaimed fibers were subsequently used to produce 50:50 recycled-cotton/cotton blended yarns in Ne 10, Ne 15 and Ne 20 counts [9]. The study demonstrated that mechanical recycling could therefore produce reclaimed fibers suitable for further spinning under the investigated conditions.

It is important to distinguish these results from those obtained for roving waste. Wanassi et al. investigated waste cotton yarn, not roving waste. Therefore, the numerical values cannot be directly assigned to roving waste. They instead demonstrate the general relationship between mechanical-recycling parameters and recovered-fiber quality.

The economic value of roving-waste recycling is associated with the possibility of replacing part of the virgin cotton input with recovered material.

Alikhonov reported that the introduction of recycled roving fibers at 20% resulted in substantial savings in cotton consumption and reduced the expected payback period of the recycling-machine investment [3].

In the industrial waste audit conducted by Alikhonov and Bobojanov, the integrated waste-management protocol resulted in a 47% reduction in roving waste generation, with a projected annual saving of US$18.50 per metric ton of production [2].

These two results should be considered separately. The first concerns the economic effect of recycling recovered roving waste, while the second concerns the economic effect of reducing waste generation through an integrated management system.

Both approaches contribute to resource efficiency, but they solve different parts of the problem.

The results demonstrate that cotton roving waste has a realistic potential to be used as secondary raw material in spinning.

The first important factor is the relatively high useful-fiber content of roving waste. Bedez Ute et al. reported approximately 95–97% good fiber for roving and comber wastes [5]. This means that roving waste should not be treated in the same manner as heavily contaminated blowroom or card waste.

The second factor is the mechanical processing intensity. Alikhonov's experimental work showed that an improved mechanical processing machine achieved up to 80% fiber recovery [3]. The machine incorporated controlled feeding and optimized opening elements to reduce fiber damage [3].

The third factor is the blending ratio. The same study showed acceptable tensile strength and evenness for medium-count yarns containing up to 20% recycled roving waste [3]. This result is consistent with the findings of Halimi et al., who reported that 15–25% secondary raw material could be incorporated under optimized rotor-spinning conditions without hardly noticeable changes in yarn quality [8].

However, these two studies should not be treated as identical experiments. Alikhonov investigated roving waste, whereas Halimi et al. investigated cotton waste and rotor-spinning parameters more generally. Their agreement nevertheless indicates that moderate incorporation levels can be technologically realistic.

The fourth factor is fiber quality after recycling. Mechanical processing can reduce fiber length and increase the proportion of short fibers. The study of Ütebay et al. confirmed that the characteristics of the initial waste influence the properties of recovered fibers [6].

The fifth factor is the design of the recycling machine. The experimental study of Kanan et al. showed that opener design had a significant influence on the quality and yield of recovered fibers from colored denim yarn waste [7]. The seven-roller opener performed better than the two-roller opener under the investigated conditions [7].

This supports the technological direction of improving mechanical equipment specifically for roving waste rather than simply applying equipment designed for another type of textile waste.



Figure 3. Machine for Recycling Cotton Roving Waste

Another important point is that recycling should be combined with waste prevention. The industrial audit conducted by Alikhonov and Bobojanov identified mechanical inefficiency as the largest single cause of roving waste formation, accounting for 42% of the identified causes [2].

Therefore, an efficient enterprise strategy should combine:

- reduction of unnecessary roving waste generation;
- controlled collection and sorting;
- mechanical opening and cleaning;
- recovery of usable fibers;
- controlled blending with virgin cotton;
- quality control of the resulting yarn.

This approach is more appropriate than treating recycling only as an end-of-pipe waste-management operation.

Conclusion. The analysis of published research demonstrates that cotton roving waste can be considered a technically valuable secondary raw material for cotton spinning.

Industrial data reported by Alikhonov and Bobojanov showed that roving waste accounted for 3.5–5.2% of production volume in the investigated spinning mills. Mechanical inefficiencies, operator handling errors and raw-material variability accounted for 42%, 31% and 27% of the identified causes, respectively [2].

Experimental work by Alikhonov demonstrated that an improved mechanical roving-waste processing machine could achieve a fiber recovery rate of up to 80%. The same investigation found that yarn containing up to 20% recycled roving waste demonstrated acceptable tensile strength and evenness for medium-count yarns [3].

Other experimental studies on cotton waste confirm that mechanical-processing conditions, waste characteristics and blending ratio have a substantial influence on the quality of recovered fibers and yarn [5–10]. In particular, excessive mechanical processing can negatively affect fiber length and short-fiber content, while moderate blending ratios can provide acceptable yarn quality [6,8,9].

Therefore, efficient utilization of roving waste should be based on controlled mechanical opening and cleaning, preservation of useful fiber length and controlled blending with virgin cotton. The objective should not be maximum mechanical opening or maximum waste incorporation, but rather the highest practical recovery of usable fibers with minimum deterioration of their technological properties.

The results also indicate that waste recycling should be combined with measures aimed at reducing waste generation at the source. Such an integrated approach can simultaneously improve material utilization, reduce raw-material consumption and increase the economic efficiency of cotton spinning enterprises.

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