Spinning Sustainability: Turning Wool By-Products into Value

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ABSTRACT

Wool, a sustainable and versatile natural fiber derived primarily from sheep, has been an essential material throughout history for providing comfort, protection, and adaptability. With India being the third-largest sheep population country and a significant global wool producer, the wool industry contributes substantially to the textile sector. However, challenges like low per-sheep yield and textile waste require attention. Alongside wool production, the industry generates valuable byproducts such as lanolin, noils, keratin, and wool scouring sludge, each with immense potential for value addition. Lanolin, a widely used ingredient in cosmetics, lubricants, and agricultural applications, showcases its versatility. Noils are repurposed into textiles, blankets, and non-woven fabrics, while keratin finds advanced applications in biotechnology, tissue engineering, and wastewater purification. Waste wool is utilized for innovative solutions like composite materials, eco-friendly bricks, and nitrogen-rich fertilizers that improve soil health. Wool scouring sludge is transformed into compost, while wool fibers demonstrate excellent oil adsorption capabilities. Moreover, wool contributes to microbial peptone production, thermal and acoustic insulation, and handcrafted items. These innovations align with principles of circular economy and sustainability, emphasizing the importance of reusing, recycling, and repurposing wool and its by-products. By fostering innovative applications and sustainable practices, the wool industry can maximize its ecological, economic, and social value, advancing responsible

resource management and contributing to a more sustainable future.

INTRODUCTION

Throughout history, humans have relied on both animal and plant-based materials for various needs, with one of the most essential uses being protection from the elements. Wool, a natural fiber derived from animals, serves as the fleece or protective covering of sheep and other mammals, such as goats and camels. Over time, humans mastered the art of transforming these fibers into yarn and fabric, providing a versatile and functional means of clothing. Wool is a renewable resource, as sheep grow new fleece every year, making it an inherently sustainable material. Its natural properties include high UV protection, fire resistance, biodegradability, and exceptional durability. Additionally, wool is easy to care for and offers breathability, making it an ideal fabric for a range of conditions. As a natural insulator, wool adapts to the wearer's body temperature—keeping them warm in cold weather while efficiently releasing heat and moisture when the temperature rises. This unique adaptability makes wool an excellent choice for comfort and protection.

India and wool

India is the 3rd largest sheep population country in the world having 74.26 million sheep producing and 9th largest wool producing country. Our raw wool production in 2020-21 is 36.93 million kg wool. Average annual yield per sheep in India is 0.9 Kg. against the world average of 2.4 kg. per sheep per year. (*https://ministryoftextiles.gov.in)*.

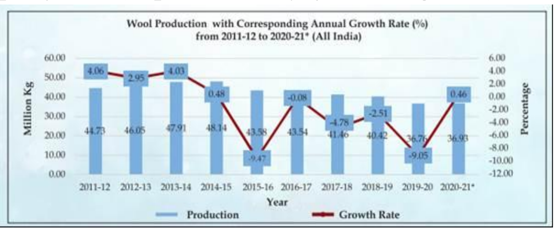

Fig 1.1. Wool production in India

Textile waste

Textile waste in India arises primarily in three waste generation streams:

1. Pre-consumer i.e., waste generated before the finished products reach the consumers and includes waste types such as spinning waste, fabric trimmings/cuttings, fabric deadstock, and unsold garment inventory;
2. Domestic post-consumer, i.e., garments/ textiles discarded by domestic consumers; and
3. Imported waste stream, which includes second-hand clothing and mutilated rags imported to India**.**

In relation to wool the different byproducts of wool consist of various wool fiber components which are generated during processing of wool to yarn and fabric. From the sourcing of raw materials to textile production, garment manufacturing, and distribution to retail stores, the wool-based textile industry produces huge amounts of waste. The use of these wastes is very economical and can increase the profit of wool processing *(*Fashion for Good, *2023).*

The various wool by products are – lanolin, noils, wool particle, wool scouring sludge etc.

Value addition of wool by products

Lanolin

Lanolin, grease obtained from sheep wool, is a complex matrix composed principally of a mixture of esters involving more than 138 different aliphatic acids, combined with about 75 different alcohols (F Allafi *et al.*, 2022).

Because lanolin's properties are similar to those of the sebum (oil) secreted by human skin, it is a popular ingredient in moisturizers, hair care products, and soaps. On molecular level lanolin is made up of alcohols and acids. In addition to moisturizing, it's good for lubrication, polishing, and waterproofing.

Fig 1.2 *Purelan TM - Lanolin Cream*

Fig 1.3- Bricks with mineral wool insulation

In the textile industries, wool wax is used to manufacture rayon, and the alcohols derived from the wax can be converted by sulfonation and neutralization into highly efficient wool scouring detergents equally effective in hard or soft water; a further product "wool oleine" is used as a lubricant in the carding and combing of wool fibers (Gillespie 1948).

It is also used as an effective carrier for plant growth "promoting hormones" in the healing of tree wounds, and as a substitute for mineral oils in insecticidal sprays in the agricultural field (F Allafi *et al.,* 2022).

Noils

During the conversion of wool fiber into yarn and fabric, the noils, soft and hard waste are generated (Sule and Bardhan, 2001). Among them, noils can be effectively utilized in blend with medium, carpet, and coarse wool for their diversification. Comber noil from Bharat merino wool at 10, 20, 30, and 40% are blended with Chokla raw wool for the development of blankets. The addition of noil increased the thickness of the blanket and bending length in warp and weft direction. It is concluded that 30% comber noil could be blended with fine and medium wool to get good thermal and smoothness properties of the woolen blanket. Other than utilization in the conventional spinning system, the noils, soft waste, and hard waste have potential applications in the preparation of non-woven fabric (Felt/Namda) (Shakyawar *et al.,* 2021).

Waste wool

Das *et al*. (2017) investigated waste wool and biochar-based hybrid composites, and showed that wool is helpful in enhancing the limit oxygen index (loi) and some mechanical characteristics such as tensile and flexural strength. The charring ability of wool helped in a gradual reduction of heat release, while the use of composite led to less smoke release and reduced peak heat release rate, in comparison with virgin polypropylene composite. Waste wool is also used in making fiber-reinforced composite bricks, where incorporation of wool gives in an increase of 37% compression strength.

Keratin from wool

Wool is an abundant source of structural protein commonly referred to as keratin. Growing interest in natural biopolymers for advanced biotechnological and biomedical applications is driving wool keratin (WK) research for novel uses. Wool keratin is both biocompatible and biodegradable and hence has potential for biomedical applications. Presence of arginine-glycine-aspartate (RGD) and leucine-aspartate-valine (LDV) sequences in wool keratin is believed to provide strong cell adhesion properties allowing it to be used as scaffolds for cell growth. (Rajkhowa *et al.,* 2012).

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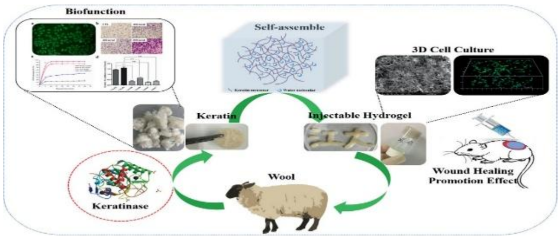

Fig 1.4 – Enzymatic Extraction of bioactive and self-assembling wool keratin for biomedical applications. Image courtesy- Su *et al.*, 2020

Keratin application for the purification of metal contaminated natural and wastewater resources can be a promising technology (Khosa and Ullah, 2013). Several metals such as mercury, copper, silver, cadmium, lead, chromium, and aluminum (Baek, 2007). Nickel (II) chloride zinc (II) and Iron (II) ion had been evaluated for removal using keratin wool(F Allafi *et al.,* 2022).

Keratin nanofiber is prepared by dissolving keratin in formic acid at 15% and spun in electro-spinning set up to get 250 nm diameter. Thermal treatment is given to improve its stability by the formation of amide bonds between acid and basic groups of some amino acid side chains. These mats could be utilised in tissue engineering as they mimic the native extracellular matrix and in wastewater treatment since they can adsorb heavy metal (Shakyawar *et al*., 2021).

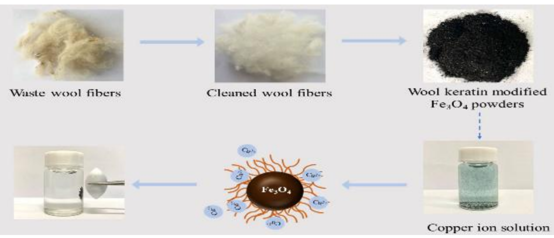

Fig 1.5 – Magnetically recyclable wool keratin modified magnetite powders for efficient removal of Cu2+ ions from aqueous solutions Image courtesy –Zhang *et al.*, 2021

Shearing sludge as compost

Raw wool when removed by shearing, and it contains a large quantity of impurities, around 35% by mass. Typical mean values by mass of different impurities are: grease (15%); sand and dirt (10%); suint (8%); and vegetable matter (2%). An essential requirement for successful wool processing is the complete removal of these impurities during the scouring process. Composting the sludge to produce a safe, saleable product could be a viable alternative (Pearson *et al*., 2004).

Wool as fertilizer

Frequent drought events due to climate change and global food demand in the coming decades urge effective actions for a more efficient use of natural resources (FAO). Sheep wool has been proposed as a raw wool constituent, particularly its protein hydrolysates, for fertilizer application. Apart from waste which has been disposed, sheep wool waste as fertilizer nutrient sources for crop plants had been proven to be a good source of nitrogen (Vončina and Mihelič, 2013). A study assessing the potential of sheep scoured wool residues (SWRs) as soil amendments to enhance the physical and hydraulic properties of a sandy loam soil under rain conditions has been done.

The effects of Sheep Wool Residues on soil physical and hydraulic properties were found to depend on the quantity and type of SWRs applied. SWRs could thus be successfully applied to enhance physical and chemical soil properties to improve soil functions as soil infiltration capacity and reduce soil erosion risk (Abdallah *et al.,* 2019).

ICAR-CSWRI has developed a compost i.e., wool waste, sheep manure, and crop residues in 30:50:20 ratio for the nutrient for indoor and outdoor ornamental plants (Kadam *et al.*, 2014).

Fiber adsorbent

Sheep wool fiber (Greener Cleaner) presents great potential as an inexpensive, easily available alternative adsorbent for oil removal. Wool has also been proven to remove diesel fuel, crude, base, vegetable, and motor oil (Radetic *et al*.,2008).

Fig 1.7 - Oil Absorbent Wool Felt

Fig 1.8- A smart, natural wool insulation for healthy buildings. Image courtesy -Nithya Caleb (2018)

Peptone from wool

Sheep wool is used to produce microbial peptone by chemical process or enzymatic methods. Among microbial culture media, Peptone is one of the most expensive lab materials. Peptones are protein hydrolysates that are prepared from proteinaceous material (Keratin is nutrition for microorganisms). They contain secondary protein derivatives such as polypeptides, dipeptides, and amino acids. They provide a readily assimilable source of nitrogen, which is water-soluble, does not coagulate upon heating, and is therefore particularly suitable for inclusion in microbiological culture media (AL-Bahri *et al*., 2009).

In building materials

Sheep wool began to be marketed and promoted as an alternative insulating material (thermal and sound) in building construction to improve the mechanical and ecological performances, as well as creates a link between textile and construction markets (Corscadden *et al*., 2014; Zach *et al*.,2020).

Handcrafted items

Other than yarn production, medium-coarse and coarse wool have been utilized for the preparation of handicrafts and namda. Still, coarse wool is not fully utilized due to its large diameter, high bending rigidity, and torsional rigidity. To mitigate this problem, ICAR-CSWRI has conducted research programs to develop diversified products Turquoise woven foot mat, winter baby bed, striped doormat, embroidered bolster cushion, elliptical bath mat, braided yarns, and felt ball using braiding and sliver felting methods.

Fig 1.9 Handicraft items by ICAR-CSWRI

CONCLUSION

Responsible resource management and material usage in the twenty-first century are now driven by sustainability and innovation. In order to ensure social, economic, ecological, and environmental benefits as well as the wellbeing of those working in the industry, we need a regenerative system where textile, its products and by products are circulated until its maximum value is retained for as long as possible through reusing, recycling or value addition. Other than conventional applications, wool can be explored as a material for insulation, acoustic, and construction, bullet-proofing, automobile, and agriculture through diversified product development by products of wool have found various usage in many different fields therefore its value addition will help us to utilize it to the maximum with much better applications.

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