Flexible technologies of processing textile wastes into high added value products

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Abstract

The overexploitation of natural resources and environmental degradation, will lead to severe and irreversible changes for people, economies and ecosystems, around the world. Anthropogenic pollution and greenhouse gas emissions will further increase global warming, ocean acidification, desertification and changing climate patterns. People must re-establish symbiosis and live in harmony with the environment.

The textile industry is considered as ecologically, one of the most polluting industries in the world. Innovation can play an important role in supporting the textile industry, especially in respect of identifying new ways to recycle textile materials and opening new business opportunities.

The aim of the paper is to implement innovation towards a more sustainable use of textile materials. In this context, there was elaborated the non-conventional technology for the processing of textile wastes resulted from garment manufacturing, which could include and functionalized fibers/ yarns. The results can maximize the value of recovered material. A basic direction of the research was the optimization of the technological parameters related to the primary operations of the textile waste, resulting from the garment operations, in recovered fibers, in order to exploit the technological potential in value-added products.

Keywords

recycling, nonconventional, textile waste, optimization

Introduction

Overexploitation of natural resources and environmental degradation, these will lead to severe and irreversible changes for people, economies and ecosystems around the world. Anthropogenic pollution and greenhouse gas emissions will further increase global warming, ocean acidification, desertification and changing climate patterns. We must re-establish symbiosis and live in harmony with the environment [1]. We live unsustainably, which leads us vertiginously to the irreversible damage to the ecosystem (Table 1) [2]:

Table 1 Causes of environmental changes with their effects

Environmental changes	***Causes***	***Effects on***
Climatic changes; Melting the glaciers; Increasing ocean levels; Deforestation; Reducing biodiversity; Soil degradation/desertification; Diminishing resources; Movement of the population; Political and social issues.	<u>Natural causes</u> *a) Cosmic factors:* the solar activity, the change of the inclination of the elliptic (the angle formed by the Earth with its orbital plane), the change of the position of the perihelion (the closest point of the Earth to the Sun), the variations of the terrestrial orbit, the displacement of the polar axis position on the elliptic plane, the cosmic carp *b) Terrestrial factors:* continental drift, altered heat flow inside the Earth, volcanism, earthquakes, extreme climatic phenomena, changes in ocean currents, the presence of underwater thresholds, changes in atmospheric circulation dynamics. <u>Anthropogenic causes:</u> population growth, urbanization, agricultural activities, industrial and construction activities, political / geopolitical activities	Relief ; Climate; Water resources ; Biosphere; Soils; Population; Economy; Social and political security.

The impact of climate change on human health is so severe today that it could be considered the "major threat of the 21st century".

The combination of obesity, malnutrition and climate change is the biggest threat to human health and the planet, which is already affecting one way or another each country in the world [3]. They are a syndemic, or a synergy of epidemics, because they happen at the same time and place, interacting with one another and producing complex problems (Table 2) [4].

Table 2 Global outcomes of the consequences of intersecting natural and human systems

A. Global outcomes view				B. Global Syndemic view			C. Five feedback loops				D. Individual view
Natural systems				Climate change	Undernutrition	Obesity					Walker
Governance		Societal determinants	Human systems				Governance loops				Voter
Norms Economics Policies											
Macro systems								Business loops Ecological loops		Health loops	Customer
Food Transport Urban design Land use											
Meso systems	Environments								Supply and demand loops		Employee
Schools Hospitals Workplaces Public spaces											
Micro systems											Parent
Families Communities Social circles											

Note. Adapted from "The Global Syndemic of Obesity, Undernutrition, and Climate Change -*The Lancet* Commission report", 2019, The Lancet, Volume 393, Issue 10173, pages 791-846, Copyright © 2019 Elsevier Ltd.

As shown in Table 2, health or ecological health and wellbeing of humans are influenced by their specific attributes and the environments created by them, respectively by the effect produced by the intersection of the natural and the human system. Individuals inhabit all layers of human systems (micro/family, community, social circles, meso/schools, hospitals, workplaces, public spaces, macro/transport, land use, etc.) that are in permanent interaction with each other and with natural ecosystems. Non-linear associations are created between cause and effect, interdependencies are multiple, they can change over time and generate more interaction, consolidation and balancing feedback loops. Five important reaction loops are considered for evaluation: health loops, business loops, supply and demand loops, governance loops.

"Protecting and improving the quality of the environment, in accordance with the economic and social needs of Romania, thus leading to a significant improvement of the quality of life by encouraging sustainable development" is a global objective of economic and research activity.

In this context, the wastes represent a major problem in each country and the quantities of wastes are generally increasing. The generating of wastes is involving a loss of material and energy and means high economic and environmental costs for society for collecting, treating and processing them. It is hard to imagine living in a world without textiles. Nearly everyone, everywhere comes into contact with them nearly all the time [5].

The textile industry is considered as ecologically one of the most polluting industries in the world. Innovation can play an important role in supporting the textile industry, especially in respect of identifying new ways to recycle textile materials and opening new business opportunities. The following areas may adversely affect the sustainability of the textile industry: use of toxic chemicals; water consumption, energy consumption, waste production, air emissions, transportation and packaging materials [6]. The industry has been responsible for creating land, air and water pollution affecting human health and damaging the eco-system [7]. Due to the diverse nature of fibrous waste, a variety of waste management practices and technologies must work in concert in an integrated industry in order to increase the rate of recycling [8]. Textile recycling offers the following environmental benefits: decreases landfill space requirements, avoided use of virgin fibers, reduced consumption of energy and water, pollution avoidance, lessened demand for dyes [9].

Within the "waste hierarchy" established at EU level, the priority is prevention, followed by reuse, recycling, recovery and least-favored option, disposal (which includes the storage and incineration of waste without energy recovery) [10].

Considering the potential technological value of the textile waste resulting from the garment sector, the processing technology of the textile wastes was elaborated respecting the following aspects:

- the establishing of the relation between the feeding speed of the cutting machine, the number drums and the length of the recovered fibers;
- the establishing of the variation limits of the basic characteristics of the recovered fibers destined for the processing on rotor spinning systems;
- the establishing of the optimum bonding-fiber percent in the conditions of assuring the resistance-characteristics of the fibers;
- assuring of the color uniformity;
- establishing of the technologic adjustments which should permit the processing of the fibrous blend with maximum content of recovered fibers;
- obtaining of fibers with physical-mechanical characteristics, which should assure the processing in weaving process.

The technologic chain can be considered as being formed of three important steps:

- the preliminary preparation, which includes operation of cutting, waste breaking;
- the blending of the recovered fibers with bonding fibers, which are realized in the operations of pre-blending, blending, carding;
- non-conventional spinning of the fibers blends.

The experiments carried out were aimed at establishing mathematical models expressing the connection between the main technological parameters of the cutting machine and the breaker and the physico-mechanical characteristics of the recovered fibers. The textile materials under study were in the form of knitted scraps resulting from the manufacturing operations. Factor programming of the experiment was used to address the problem.

The choice of the independent variables was made considering the possible limits of regulation as well as the degree of influence on the basic characteristic of the recovered fibers, respectively the length of the fiber.

Independent variables

x_1 – feeding speed of the cutting machine, having a variation range of (3-27) m/min.

x_2 – the order number of opener drums, having a variation range of 2-8.

The codification was made in such a way as to encompass the entire possible field to be achieved from an ethnic point of view (Table 3).

Table 3 The connection between the main technological parameters of the cutting machine and the breaker and the physico-mechanical characteristics of the recovered fibers

Parameter name	***Unit***	***Code***	***-1.414***	***1***	***0***	***+1***	***+1.414***
feeding speed of the cutting machine	m/min	x_1	3	6.5	15	23.5	27
the order number of opener drums	no.	x_2	2	3	5	7	8

Dependent variable

y_1 = the length of the fibers recovered.

The experimental data analyzed by the multiple regression method led to the equation $y=f(x_1, x_2)$ respectively:

$y_1=6.901+0.835x_1-1.840x_2-0.271x_{12}-0.417x_{22}$

The developed model was validated by the tests t and F, the suitability being certified by the small differences between the experimental and the calculated values.

Increasing the number of drums from the breaker has as a consequence the reduction of the length of the recovered fibers, thus limiting the range of fine yarns that can be obtained.

Processing in conditions where x_1[0,1] , real values [15; 23,5] m/min and x_2[-1,0], real values of [3-5] drums, ensures technological conditions for obtaining the corresponding recovered fibers in terms of length.

The spinning technological experiments have indicated the fact that from a blend made up of 70% recovered fibers from reusable textile materials under study, and 30% binding fibers, there can be obtained 50-100 tex yarns having adequate physical and mechanical characteristics (Fig.1).

a) b) c) d)

Fig. 1 Characteristic elements of technologic flow: a) textile waste; b) recovered fibers c) open end yarn spun; d) decorative products made of yarn containing recovered fibers

A synthesis of the main characteristics values for the analyzed variants indicate the following variation limits (Table 4):

Table 4 A synthesis of the main characteristics values for the analyzed variants

Characteristics	***70% recovered fibers / 30% binding fibers***		
	50 tex	71 tex	100 tex
CV – tex (%)	1.6 – 4.2	2.1 – 3.0	1.6 – 3.6
Yarn tenacity (cN/tex)	5.8 – 7.8	5.4 – 7.2	5.5 – 8.6
CV – tensile strength (%)	7.0 – 15.0	7.5 – 13.6	7.1 – 14.0

The processing system is flexible, the maximum content of recovered fibers in the fiber blend is of 70%; the option regarding the nature of the bonding-fibers (celo-fiber or PES) is of economic option, the technological chain assures the color – uniformity of the yarns (by using the base color of the recovered fibers), what permits the elimination of the dying operation of the finished products;

Conclusion

Textile elements or systems are present in all areas of economic, social and strategic activity being a basic pillar of the sustainability of mankind, given that the textile industry is considered to be the second largest polluter in the world, understanding the real impact of the textile-clothing industry requires a in-depth review of the value chain.

The limits of the current linear economy model (take-make-waste) are extremely evident when looking at the textile industry.

Moving to a circular economy requires significant changes in both production and consumption patterns, requires a change at system level with a degree of commitment, collaboration and innovation.

The vision of a new textile product economy is a powerful impulse for new ideas that would redirect the attention of researchers.

Textile recycling offers the following environmental benefits: decreases landfill space requirements, reducing the consumption of natural fibers, energy, water and dyes, protecting the environment and human health, using textile fiber both as technical textiles and as raw material, in specific loop of LCA.

Acknowledgements

This work is funded by the UEFISCDI Romania, within PN III, 1st Program/ Subprogram 1.2 – Institutional Performance - Complex projects completed in R&D consortia, project no. 11PCCDI/ 2018-2020 and the publication of the article is funded by the Ministry of Research and Innovation within Program 1- Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, Contract no. 6PFE/2018.

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