Green Dyeing of Polyamide with Increased Anti-UV Properties

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INTRODUCTION

During the last few decades, ecological concerns related to the use of the synthetic dyes, have led to a greater motivation for the development of processes that use natural products. This strategy has been applied to improve the increasingly necessary sustainability of wet textile processes.

Natural dyes are available in nature in different shades and they can be exploited for coloring textiles and to improve other properties such as UV protection and antimicrobial activity. Among them, those obtained from eucalyptus leaves, mainly composed by tannins (gallic acid and ellagic acid) and flavonoids (quercetin and rutin), appear to be interesting for textile finishing applications. The eucalyptus leaves, are an abundant, inexpensive and readily available forest residue. However, despite the recognized properties of this type of compound, its use in polyamide dyeing was not reported in our literature review.

The present study aimed to develop dyed polyamide 6 knitted fabrics with increased UV protection using a natural eucalyptus leaves extract.

METHODS

The eucalyptus leaves extract was obtained and characterized in aqueous medium. This extract was applied to polyamide 6 knitted fabrics using an exhaustion process. The main parameters of the dyeing process, such as temperatures and pH, were optimized. The dyed samples were analyzed for color intensity and the washing, rubbing and perspiration fastness properties were also evaluated according to the ISO standard protocols. Moreover, the UV protection factor (UPF) was measured according to the standard method AS/NZS 4399:1996.

RESULTS AND DISCUSSION

Chemical characterization of the eucalyptus extract by HPLC/MS-MS

Table 1 shows the list of compounds identified in the eucalyptus leaf extract through HPLC / MS-MS, as well as the respective retention times (TR), detected mass $[M\text{-}H]^-$, ion fragmentation profile and bibliographic references used to make the identification.

Table 1 - Chemical characterization of the eucalyptus extract by HPLC/MS-MS

Number	TR (min)	Compound name	$[M\text{-}H]^-$ (m/z)	MS/MS	Reference
1	2.07	Quinic acid	191	127, 93, 85	(Abdel-Hameed et al., 2013)
2	5.23	Galloyl-hexahydroxydiphenyl-glucose	633	481, 301	(Boulekbache-Makhlouf et al., 2013; Zhu et al., 2015)
3	5.33	Gallic acid	169	125, 124, 79, 51	(Lan et al., 2013)
4	5.96	Galloyl-hexahydroxydiphenyl-glucose	633	481, 301	(Boulekbache-Makhlouf et al., 2013; Zhu et al. 2015)
5	6.71	Galloyl-hexahydroxydiphenyl-glucose	633	481, 301	(Boulekbache-Makhlouf et al., 2013; Zhu et al., 2015)
6	7.02	Protocatechuic acid-hexoside	315	153	(Catarino et al., 2015)
7	7.05	Bis(hexahydroxydiphenyl)-glucose	783	481, 301	(Boulekbache-Makhlouf et al., 2013; Zhu et al., 2015)
8	7.23	Bis(hexahydroxydiphenyl)-glucose	783	481, 301	(Boulekbache-Makhlouf et al., 2013; Zhu et al., 2015)
9	7.52	Chlorogenic acid	353	191	(Santos et al., 2011)
10	8.90	Ellagic acid	301	229, 185, 173, 157, 146	(Santos et al., 2011)
11	9.10	Quercetin 3-O-glucuronide	477	107, 151, 179, 301	(Horai et al., 2010)
12	9.34	Quercetin-hexoside	463	300, 271, 254, 179, 151	(Abdel-Hameed et al., 2013)
13	9.38	Kaempferol O-glucuronide	461	285	(Zhu et al., 2015)
14	11.65	Quercetin	301	179, 165, 151, 121, 107	(Santos et al., 2011)

Dyeing Process Optimization

Among the different dyeing conditions tested, samples dyed at pH 3.5 and 100 °C gave the best dyeing yield with inherent increased color intensity (figure 1).

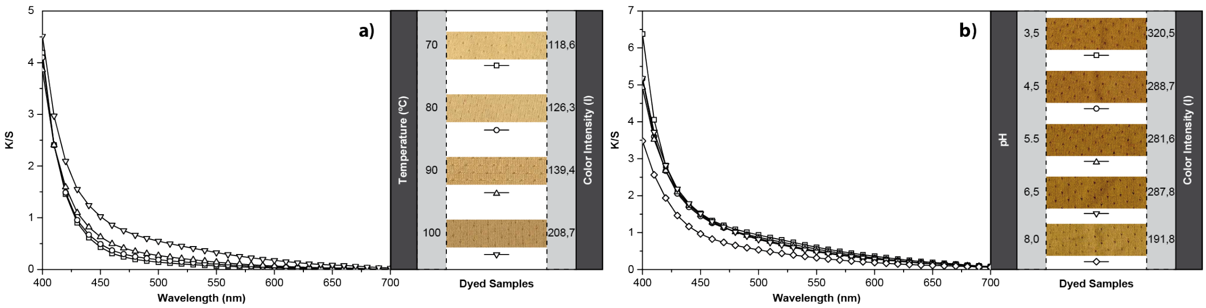

Figure 1. Dyeing yield obtained under different temperature (a) and pH (b) conditions.

However, as can be seen in the figure 1, the hue of the dyed samples changes significantly with the pH, as confirmed by their CIELab color coordinates (figure 2).

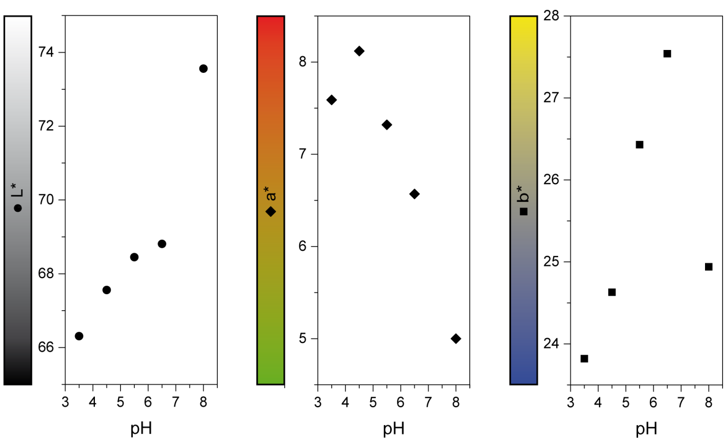

Figure 2 – CIELab Color coordinates of dyed samples as a function of dyebath pH

Regarding to fastness properties, the samples dyed under the best dyeing conditions showed good washing and rubbing fastness properties (table 2), as well as good color fastness to perspiration (table 3) and reasonable light fastness properties (figure 3).

Table 2 – Washing ad rubbing fastness

Wash fastness							Rubbing fastness	
Color change	*Staining on adjacent fibers*						*Dry*	*Wet*
	WO	*PAC*	*PES*	*PA*	*CO*	*CA*		
4	3-4	4	5	3-4	4-5	4-5	5	5

Table 3 – Color fastness to perspiration

Test	Color fastness to perspiration						
	Color change	*Staining on adjacent fibers*					
		WO	*PAC*	*PES*	*PA*	*CO*	*CA*
Acid perspiration	4	4	5	5	4-5	5	5
Alkaline perspiration	4	3-4	4-5	4-5	4	4-5	4-5

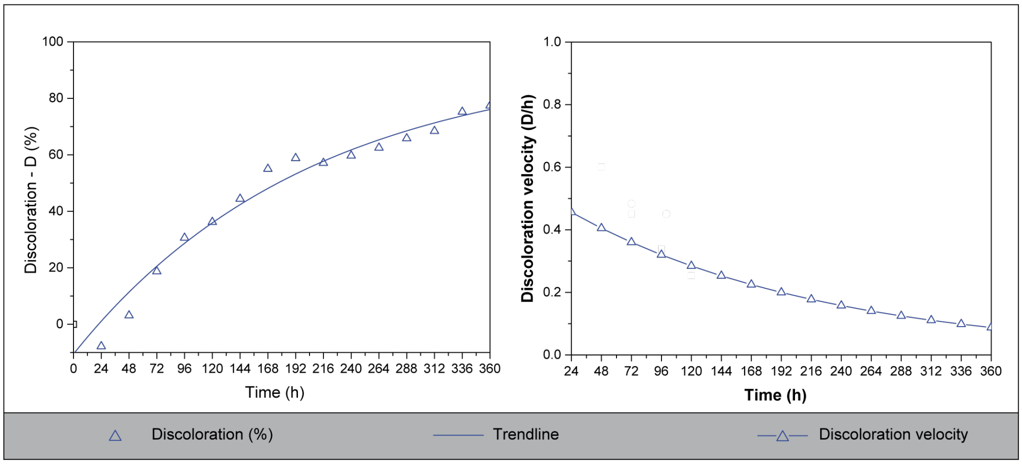

Figure 3 – Light fastness

Ultraviolet Protection Factor (UPF)

Although color intensity increased with extract concentration (5 to 80 gL^{-1}), it was found that 5 gL^{-1} was sufficient to obtain the best UV protection results.

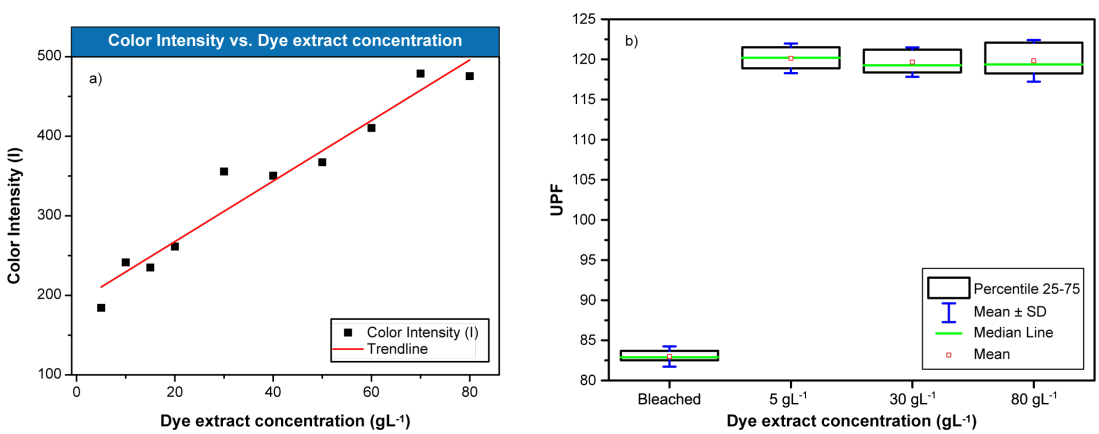

Figure 4 – Color intensity vs. dye extract concentration (a) and UPF vs. dye extract concentration (b)

CONCLUSIONS

The work developed allowed to establish the process conditions for a sustainable dyeing of polyamide with eucalyptus extract. The dyed materials showed good fastness properties and higher UV protection.

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