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New thickening agents based on tamarind seed gum and karaya gum polysaccharides

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ABSTRACT

Wool, silk and nylon-6 fabric samples were printed with reactive dyes using new thickening agents based on polymerisation adducts of acrylic acid (AA) with tamarind seed gum (TG), or karaya gum (KG) in comparison with the conventional guar gum (GG) thickener. The obtained data indicate that: (i) the printing efficiency is governed by the performance of the thickening agents, i.e. PAA/TG2 > PAA/TG1 > PAA/KG1 > PAA/KG2 > GG, as well as the nature of substrate, i.e. wool > nylon-6 > silk, (ii) the *K*/*S* values and fastness properties of the printed fabrics are determined by the type of reactive dye, and (iii) optimal printing properties, i.e. higher depth along with better fastness ratings, were achieved by using a printing paste containing PAA/TG2 (7.5%, w/w); reactive dye (30 g/kg); urea (50 g/kg); and citric acid (10 g/kg), followed by drying at 85 °C for 5 min, and steaming at 105 °C for 30 min.

1. Introduction

The two prominent protein fibres are namely wool and silk. Wool fiber is amino fiber of animal origin with predominance of $-NH_2$ and $-NH$ groups associated with wool keratin. The chemical reactivity of keratin is largely attributed to the amino acids, cystine, which may be readily oxidized, reduced or hydrolysed to give a variety of complex reaction products. On the other hand, silk is continuous protein filament formed from amino acids. Fibroin is main component of degumming silk. Glycine, alanine and serine constitute the three major amino acids. Unlike wool keratin, silk fibroin has no cystine residues.

Polyamide-6 $[-NH(CH_2)_5\,CONH\,(CH_2)_5\,CO-]$ is produced by the self-condensation of an amino acid or derivative such as lactam, i.e. caprolactam. Regardless of whether the polyamide type is 6 or 66, the terminal groups of the chains may be amino or carboxylic groups.

Natural thickening agents are high molecular weight biopolymer based on polysaccharides with plenty of hydroxyl groups. They are obtained from: plant exudates, e.g. gum karaya, gum Arabic, and gum traganth, seed or root of plant, e.g. guar gum and locust bean; as well as extracts of seaweed, e.g. alginate. Many attempts have been made to modify the chemical structure of these natural thickeners via etherification, esterification and/or polymerization in presence of different vinyl monomers to overcome their inherent drawbacks as well as to upgrade their thickening efficiency for attaining high quality prints (Dawson & Hawkyard, 2000; El-Zairy, 2003; Ibrahim, Rashad, & Abo-Shosha, 2003; Partnaik & Chakraboryt, 1995).

Additionally the demands for machine washable wool and silk prints have promoted interest in the use of reactive dyes. Using reactive dyes offers the following advantages: better solubility, shorter fixation, brilliance of shade as well as excellent fastness properties due to the higher extent of interaction of their functional groups with the active site of the aforementioned substrates.

With the above in mind, the present work deals with the reactive printing of wool, silk and nylon-6 using new thickening agents based on polymerization products of acrylic acid with tamarind seed gum or karaya gum.

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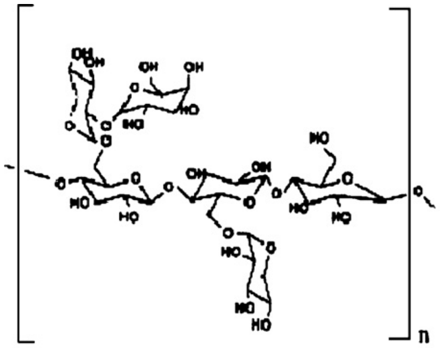
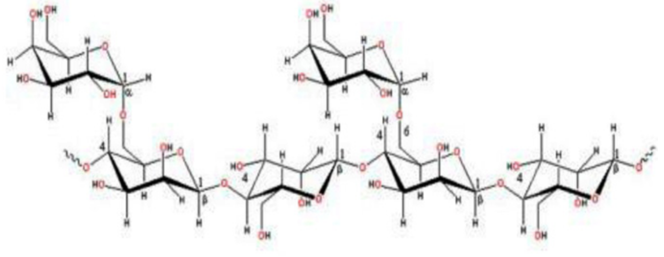
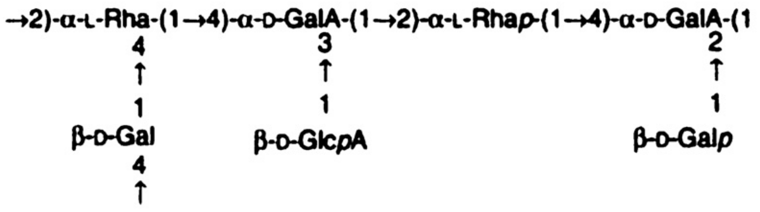


Average primary structure of tamarind seed polysaccharide



Chemical structure of guar gum



Structure elements of gum karaya

2. Experimental

2.1. Materials

2.1.1. Substrates

Mill-scoured and chlorinated plain woven merino wool fabric of 200 g/m^2, degummed and bleached plain woven silk fabric of 48 g/m^2, as well as mill-scoured nylon-6 fabric (210 denier/35 filament) were used.

2.1.2. Reactive dyes

Telon® Red BN 02 (Dystar), Telon® Yellow RW (Dystar), Levavix® Golden Yellow PN-GR (Dystar), as well as Realan® Red G (Dystar) were used without further purification.

2.1.3. Thickenings agents

Karaya gum, KG, is partially acetylated complex polysaccharide with high molecular weight containing approximately 8% acetyl groups and around 37% uronic acid residues (locally purchased). Tamarind seed gum, TG, is a high molecular weight, nonionic carbohydrate polymer consisting of a main chain or β-D-(1-4) linked glucopyranosly units, with a side chain consisting of a single xylopyranosyl unit attached to every second, third and fourth D-glucopyranosly unit through and an α-D-(1-6) linkage (Noven UK Ltd.). Diagum® A8, guar gum GG, depolymerized glactomannans was supplied by BF Goodrich Diamalte GmbH, Munich, Germany.

Polyacrylic acid/karaya gum adducts (PAA/KG1 and PAA/KG2) as well as polyacrylic acid/tamarind seed gum adducts (PAA/TG1 and PAA/TG2) were prepared by free radical polymerization of acrylic acid with the aforementioned gums, using sodium persulfate ($Na_2S_2O_8$) and sodium thiosulfate ($Na_2S_2O_3{\cdot}5H_2O$) as a redoxy system, according to methods described elsewhere (Abo-Shosha, EL-Zairy, & Ibrahim, 1994; Abo-Shosha, Ibrahim, Allam, & El-Zairy, 2008; Ibrahim et al., 2003). Characterization of the prepared adducts is shown in Table 1. All used gums and prepared adducts were ground before use.

2.1.4. Auxiliaries and chemicals

Hostapal® CV (anionic-textile auxiliary based on alkylaryl polyglygcol ether, Clariant), was of commercial grade. Citric acid, sodium hydroxide and urea were of laboratory grade chemicals.

3. Methods

3.1. Printing pastes

Reactive printing of wool, silk and nylon-6 fabrics was carried out using the following printing paste components (Table 2).

3.1.1. Printing technique

Printing pastes were applied to the used substrates using flat screen technique. Printed fabric samples were then dried at 85 °C for 5 min and steam-fixed at 105 °C for 30 min using Ariolt® CSL steamer - Italia.

After steam fixation the printed fabric samples were rinsed thoroughly with cold water, warm water, soaped for 15 min at 90 °C in presence of 2 g/L Hostapal® CV, then rinsed well with warm water, cold water and dried at 85 °C for 5 min.

3.1.2. Testing

The rheological properties of the thickening agents solutions were measured at $25 + 0.1$ °C using a co-axial rotary viscometer (HAAK V20, Germany).

The apparent viscosity (η) was calculated using the following formula: $\eta = \tau/D$ Pa s, where D and τ are the rate of shear $(\mathrm{s})^{-1}$ and shear stress (dyne/cm), respectively.

Depth of acid prints, expressed as K/S, was measured at the wavelength of maximum absorbance using an automatic filter spectrophotometer and calculated by the Kubelka–Munk equations (Judd & Wyszecks, 1999): $K/S = (1-R)^2/2R$, where K is the absorption coefficient, S is the scattering coefficient, and R is the

Table 1
Characterization of the prepared adducts.

Property	Gum type			
	KG[a]		TG[a]	
AA/gum ratio	1/1	2/1	1/1	2/1
Total conversion (%)	99.72	99.80	98.6	99.9
Solidification time (min)	6	4	5	3
Appearance of powder form	Beige powder	Off-white powder		
Water solubility (at 25 °C)	Soluble	Soluble	Soluble	Soluble
Viscosity[b] of 7.5% (w/v) aqueous solution of PAA/gum adduct (poise)	4	4.80	11.75	15.20

AA: acrylic acid; KG: karaya gum; TG: tamarind seed gum [AA] = 6.75 mol/L; [$Na_2S_2O_8$] = 34.9×10^{-3} mol/L; [$Na_2S_2O_3 \cdot 5H_2O$] = 26.87×10^{-3} mol/L; degree of neutralization of AA (20%); polymerization reaction at 90 °C for 30 min.

[a] AA/KG or TG ratio: 1/1 or 2/1.

[b] Viscosity measurements at shear rate of [12 $(s)^{-1}$].

reflectance of the printed samples at the wavelength of maximum absorbance. The higher the *K*/*S* value is, the darker the depth of the print.

Color fastness to washing, rubbing and perspiration were assessed according to AATCC Test Methods: (61-1972), (8-1972) and (15-1973), respectively.

4. Results and discussion

In this study, attempts have been carried out to evaluate the thickening efficiency of new poly (acrylic acid)/tamarind or karaya gum adducts in printing of wool, silk and nylon-6 fabrics as alternative to natural thickeners. The obtained results along with appropriate discussion follow.

4.1. Thickener concentration

As far as the change in *K*/*S* values of the printed fabric samples as a function of thickening agent, PAA/TG2, concentration and for a given set of printing conditions, Fig. 1 shows that: (i) increasing thickener concentration from (5.5%, w/w) up to (7.5%, w/w) results in an improvement in the depth of the obtained prints regardless of the used substrate, (ii) the extent of improvement is determined by the surface morphology, fabric structure chemical composition, functional groups, hydrophilicity/hydrophobicity ratio, dye affinity as well as mode of interaction of the printed substrate, and can be ranked as follow: Wool ≫ Nylon-6 > Silk, (iii) the improvement in the *K*/*S* values of the printed fabric samples reflects the positive impact of proper thickener concentration on increasing the viscosity of the printing paste and reducing the undue penetration or flushing of the released dye from the thickener film (Ibrahim et al., 2003), and (iv) further increase in thickener concentration, i.e. beyond 7.5% (w/w), has practically no effect on the depth of the obtained prints, expressed as *K*/*S* values.

4.2. Urea concentration

For a given printing paste composition, and for a given range of urea concentration (0–100 g/kg), Fig. 2 shows that: (i) increasing urea component in the printing paste up to 50 g/kg results in an improvements in *K*/*S* values as a direct consequence of aiding solution of the dye in the print paste, acting as a humectants, promoting swellability of the fabric structure as well as swellability and accessibility of its active sites during steaming, thereby increasing the extent of dye/fiber interactions and fixation, i.e. better color yield, irrespective of the used substrate (Bell, 1988; Ibrahim et al., 2003; Provost, 1992), (ii) the *K*/*S* values of the printed fabric samples follow the decreasing order: Wool (28.17) ≫ Nylon-6 (18.99) > Silk (17.81), and (iii) further increase in urea concentration has practically slight or no effect on the depth of the obtained prints.

Table 2
Printing paste compositions.

Constituent	g/kg paste
Reactive dye	30
Stock thickening (5.5, 7.5 or 9.5%)	500
Urea	50
Citric acid	10
Water	410

4.3. Citric acid concentration

Fig. 3 shows the effect of citric acid concentration on the depth of wool, silk and nylon-6 prints. It is clear that, within the range examined, increasing citric acid concentration up to 10 g/kg results in a dramatic improvement in *K*/*S* values of the obtained prints, most probably due to the positive impact of citric acid on the swellability of the fabric structure during steaming, as well as the availability and accessibility of protonated amino groups as potential dye sites on and/or within the fabrics structure, thereby improving the extent of picking up and binding reactive dye anions (Church, Darie, Scammells, & Tucker, 1999; Gulrajani, 1993). Further increase in citric acid concentration, i.e. beyond 10 g/kg, brings about a decrease

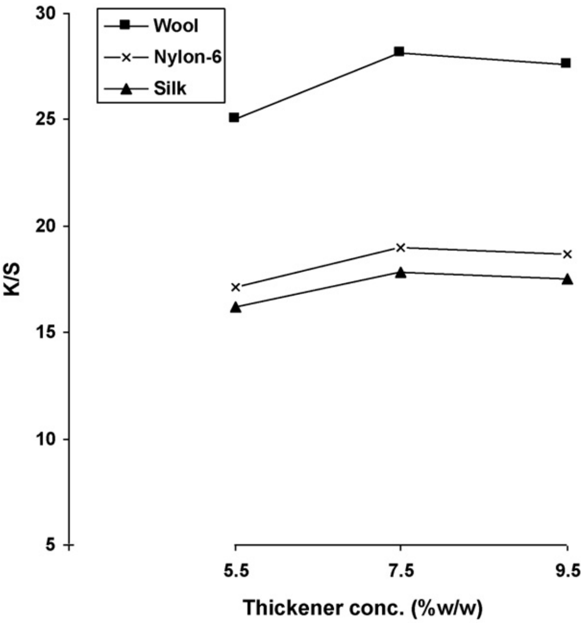


Fig. 1. Effect of thickener concentration on the depth of the obtained reactive prints. Levafix® Golden yellow BN (30 g/kg); urea (50 g/kg); citric acid (10 g/kg); drying at 85 °C/5 min; steaming at 105 °C for 30 min.

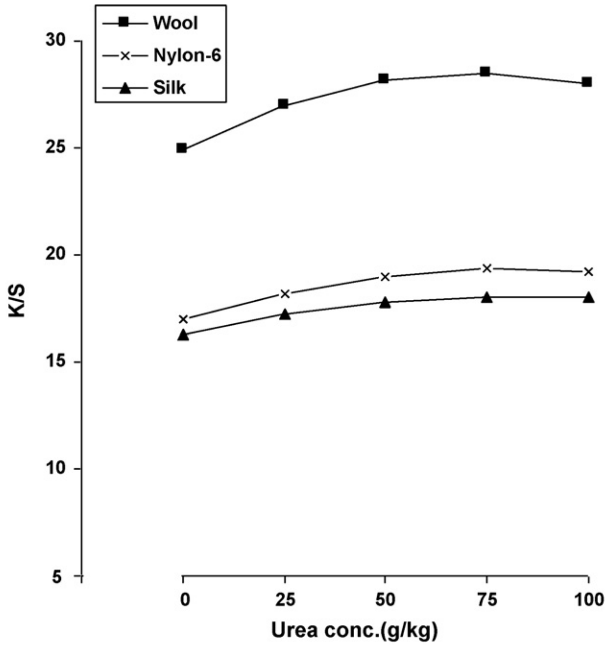


Fig. 2. Effect of urea concentration on the depth of the obtained reactive prints. Levafix® Golden yellow BN (30 g/kg); thickener (7.5%, w/w); citric acid (10 g/kg); drying at 85 °C/5 min; steaming at 105 °C for 30 min.

in the *K*/*S* values, regardless of the used substrate, reflecting the negative impacts of higher citric acid concentration on: the reheological properties of the thickening agent, the stability of the reactive dye, shortage in free amino groups and/or occupying of most of reactive sites by the acid anions, i.e. restricts the dye anions of larger size to sites of lower reactivity, as well as the dye–fiber bond stability, thereby minimizing extent of dye uptake and subsequent fixation onto and/or within the investigated substrate with the certainty that the extent of increase or decrease in *K*/*S* values is determined by the nature of the substrate (Bell, 1988; Bruce & Broadwood, 2000; Church et al., 1999; Gulrajani, 1993; Partnaik & Chakraboryt, 1995).

4.4. Reactive dye concentration

For the changes in *K*/*S* values of the printed fabric samples as a function of the Levafix® Golden yellow concentration, as well as for a given printing paste composition, Fig. 4 shows that increasing the dye concentration, from 10 up to 40 g/kg, results in a remarkable improvement in the depth of the obtained prints, irrespective of the used substrate. This could be explained by the large availability of the dye molecules in the vicinity of the available binding dye sites onto and/or within the fabric structure (Ibrahim et al., 2003). Moreover, the higher *K*/*S* values of printed wool fabric samples reflects the availability and accessibility of greater number of appropriate active/binding sites onto and into the wool structure, as well as minimum undue penetration of the used dye molecules within the fabric structure, comparing with other substrate, i.e. deeper depth of shade (Dawson & Hawkyard, 2000).

4.5. Steaming conditions

As can be seen in Figs. 5 and 6, and for a given printing paste composition, it was found that prolonging steam fixation time, Fig. 5, up to 30 min results in a gradual increase in *K*/*S* values, regardless of the used substrate, reflecting the positive impact of proper steam fixation time on releasing the dye molecules from the thickener film to the fabric surface, then transfer across that surface, followed by proper diffusion within the fabric structure, to its potential reactive centers and subsequent uptaking and fixing at those available active sites. Further increase in fixation time, beyond 30 min, has practically slight or no effect on the *K*/*S* values, most probably due to the shortage in unoccupied active sites (Judd & Wyszecks, 1999).

At constant steam fixation time, 30 min, increasing the steaming temperature from 100 °C up to 105 °C, Fig. 6, is accompanied by a slight improvement in the *K*/*S* values, which can be discussed in terms of better extent of dye interaction and fixation. Further increase in steaming temperature, i.e. beyond 105 °C, has practically no effect.

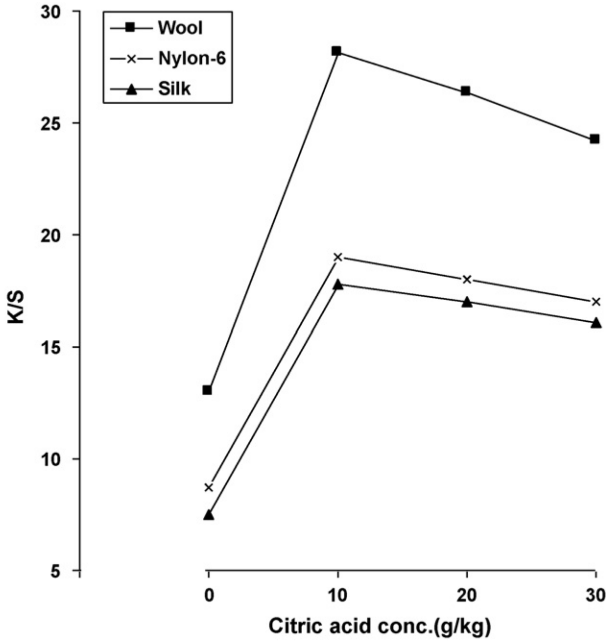


Fig. 3. Effect of citric acid concentration on the depth of the obtained reactive prints. Levafix® Golden yellow BN (30 g/kg); thickener (7.5%, w/w); urea (50 g/kg); drying at 85 °C/5 min; steaming at 105 °C for 30 min.

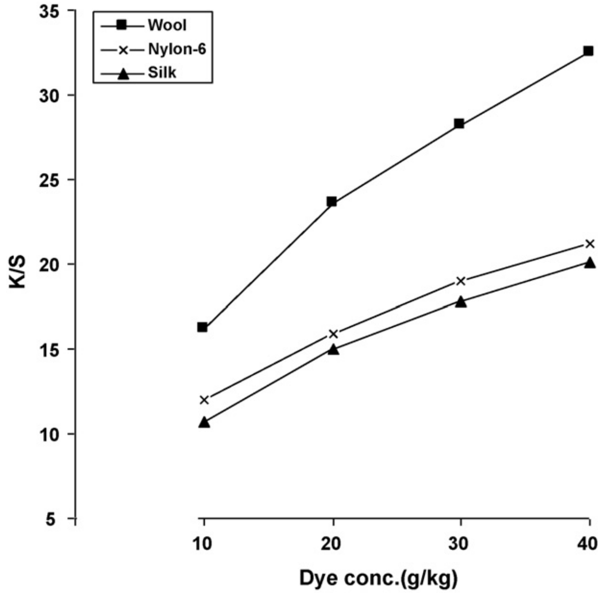


Fig. 4. Effect of dye concentration on the depth of the obtained reactive prints. Thickener(7.5%, w/w); urea (50 g/kg); citric acid (10 g/kg); drying at 85 °C/5 min; steaming at 105 °C for 30 min.

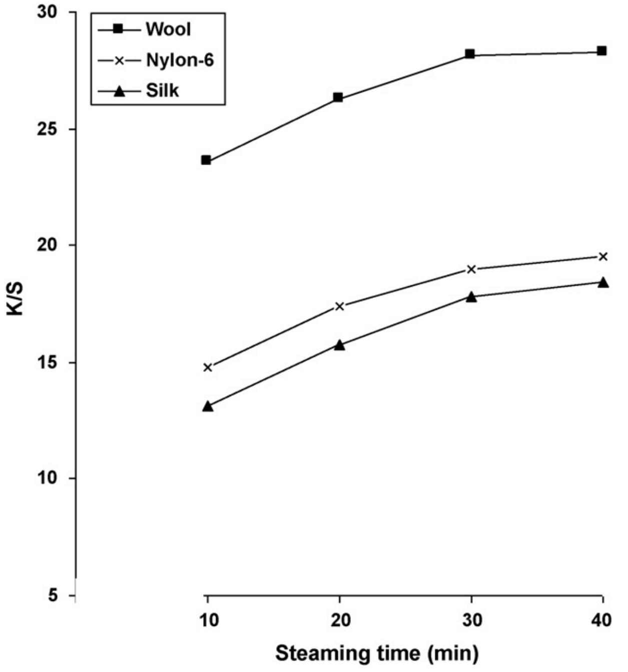


Fig. 5. Effect of steaming time on the depth of the obtained reactive prints. Levafix® Golden yellow BN (30 g/kg); thickener (7.5%, w/w); urea (50 g/kg); citric acid (10 g/kg); drying at 85 °C/5 min; steaming at 105 °C.

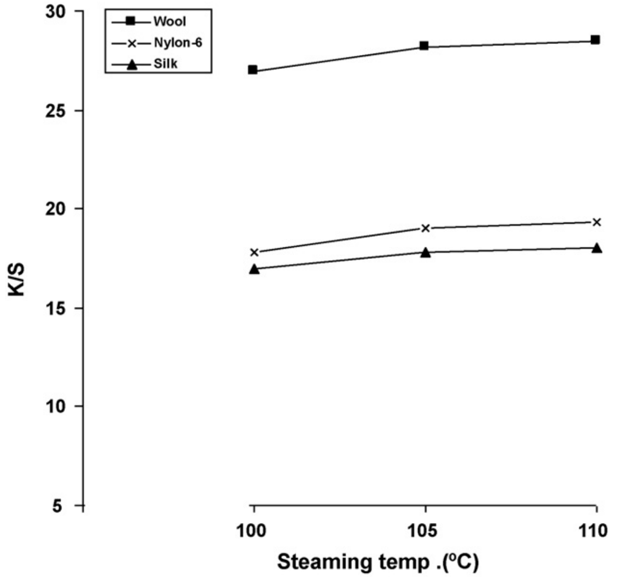


Fig. 6. Effect of steaming temperature on the depth of the obtained reactive prints. Levafix® Golden yellow BN (30 g/kg); thickener (7.5%, w/w); urea (50 g/kg); citric acid (10 g/kg); drying at 85 °C/5 min; steaming for 30 min.

4.6. *Kind of thickener and type of reactive dye*

As far as the changes in the *K*/*S* values of the obtained prints along with their fastness properties as a function of kind of thickening agent and type of reactive dye, Tables 3–5 reveal that: (i) the depth of the obtained prints is governed by the kind of thickening agent, e.g. molecular weight, chemical composition, functionality, rheological properties, thickener film properties, extent of releasing the dye molecules in the steaming step, and affinity to the used dye (Ibrahim et al., 2003; Partnaik & Chakraboryt, 1995), and follows the descending order: PAA/TG2 > PAA/TG1 > PAA/KG1 > PAA/KG2 > GG regardless of the used dye and substrate, (ii) the extent of printability of the used substrates can be ranked as follow: Wool > Nylon-6 > Silk, (iii) the *K*/*S* values as well as the fastness properties of the obtained reactive prints are determined by: the chemical composition as well as molecular structure of the dye, its functional groups, mode of interaction, affinity to the used substrates, compatibility with other paste components, extent of release from the thickener film, degree of penetration, interaction and subsequent fixation (Glover, 2005; Ibrahim et al., 2003), and (iv) using any of the new prepared thick-

Table 3
Effect of kind of thickener and type of reactive dye on the depth of shade and fastness properties of wool prints.

Reactive dye	Thickener	*K*/*S*	Incr.	WF		PF				RF	
			In *K*/*S* (%)	Alt.	C	Acidic		Alkaline		Dry	Wet
						Alt	C	Alt	C		
Telon® Red BN 02	GG	20.64	–	3–4	2–3	3	2–3	2–3	2–3	4–5	4–5
	PAA/TG1	27.87	35.02	4	4	3–4	3	3	3	5	4–5
	PAA/TG2	29.25	41.71	4	4	5	5	5	5	5	5
	PAA/KG1	27.29	32.21	3–4	3–4	4	4	4–5	4–5	5	4–5
	PAA/KG2	25.18	21.99	3	2–3	4	4	4	4	5	5
Telon® Yellow RW	GG	18.08	–	4	2–3	3–4	3–4	4	4	4	4
	PAA/TG1	22.04	21.9	4–5	4	4–5	4	4–5	4–5	5	5
	PAA/TG2	23.93	32.35	4–5	4	5	5	5	5	5	5
	PAA/KG1	21.91	21.18	4–5	4–5	5	5	5	5	5	5
	PAA/KG2	20.52	13.44	4	4	4	4	4	4	5	5
Levafix ® Golden Yellow BN	GG	16.97	–	3	2–3	4	4	4	4	4–5	4–5
	PAA/TG1	25.84	52.26	5	4	5	5	5	5	5	4–5
	PAA/TG2	28.17	66.76	4	4	5	5	5	5	5	5
	PAA/KG1	21.75	28.93	4–5	4–5	5	5	5	5	5	4–5
	PAA/KG2	19.84	16.91	4–5	4–5	5	5	5	5	5	5
Realan® Red G	GG	12.64	–	3	2	4	4	3–4	3–4	4	4
	PAA/TG1	23.16	83.22	4	3–4	5	4–5	4–5	4–5	5	4–5
	PAA/TG2	24.78	96.04	4	4	5	5	5	5	5	5
	PAA/KG1	21.25	68.11	4	3	3–4	3–4	3–4	3–4	5	5
	PAA/KG2	20.09	58.93	4–5	4–5	4	4	4	4	5	5

Printing paste composition: thickening agent 7.5% (75 g/kg paste); reactive dye (30 g/kg paste); urea (50 g/kg paste); citric acid (10 g/kg paste); drying at 85 °C/5 min; steaming at 105 °C for 30 min, followed by soaping at 90 °C/15 min in presence of (2 g/l) nonionic wetting agent. *K*/*S*: depth of shade; WF: wash fastness; PF: perspiration fastness; RF: rubbing fastness; Alt.: alteration; C: staining on white cotton.

Table 4
Effect of kind of thickener and type of reactive dye on the depth of shade and fastness properties of silk prints.

Reactive dye	Thickener	*K*/*S*	Incr.	WF		PF				RF	
			In *K*/*S* (%)	Alt.	C	Acidic		Alkaline		Dry	Wet
						Alt	C	Alt	C		
Telon® Red BN 02	GG	8.04	–	2–3	2–3	3–4	3–4	4	3–4	4–5	3–4
	PAA/TG1	14.46	79.85	3	3	4	4	4	4	4–5	5
	PAA/TG2	15.49	92.66	3	4	4–5	4–5	4–5	4–5	5	5
	PAA/KG1	14.19	76.49	3–4	3–4	3–4	3–4	4–5	4	4–5	4
	PAA/KG2	12.26	52.48	4–5	4	4–5	4–5	4–5	4–5	4–5	4–5
Telon® Yellow RW	GG	8.62	–	4	3–4	4	4	4	4	4–5	4
	PAA/TG1	14.48	67.98	4–5	4	5	5	5	5	5	5
	PAA/TG2	14.89	72.73	4–5	4–5	5	5	5	5	5	5
	PAA/KG1	13.46	56.14	4–5	4	5	5	5	5	5	4–5
	PAA/KG2	12.26	42.22	4–5	4	5	5	5	5	5	4–5
Levafix® Golden Yellow BN	GG	7.4	–	4–5	4	4	4	3–4	3–4	4–5	4
	PAA/TG1	16.02	116.4	4–5	4–5	4	4	4	4	5	5
	PAA/TG2	17.81	140.6	4–5	4–5	4–5	4–5	4–5	4–5	5	5
	PAA/KG1	14.44	95.13	4–5	4	4–5	4	4–5	4	5	5
	PAA/KG2	13.73	85.54	4–5	4–5	5	5	3–4	3–4	5	4–5
Realan® Red G	GG	5.66	–	3–4	3	3–4	3	3–4	3–4	4–5	4
	PAA/TG1	16.46	190.8	4–5	4–5	3–4	3	3–4	3–4	5	4–5
	PAA/TG2	17.55	210	4–5	4–5	5	5	5	5	5	5
	PAA/KG1	14.78	160.9	4–5	4–5	5	5	5	5	4–5	4–5
	PAA/KG2	14.2	150.9	4–5	4	3–4	3–4	3–4	3–4	5	4–5

Printing paste composition: thickening agent 7.5% (75 g/kg paste); reactive dye (30 g/kg paste); urea (50 g/kg paste); citric acid (10 g/kg paste); drying at 85 °C/5 min; steaming at 105 °C for 30 min, followed by soaping at 90 °C/15 min in presence of (2 g/l) nonionic wetting agent. *K*/*S*: depth of shade; WF: wash fastness; PF: perspiration fastness; RF: rubbing fastness; Alt.: alteration; C: staining on white cotton.

Table 5
Effect of kind of thickener and type of reactive dye on the depth of shade and fastness properties of nylon-6 prints.

Reactive dye	Thickener	K/S	Incr.	WF		PF				RF	
			In *K*/*S* (%)	Alt.	C	Acidic		Alkaline		Dry	Wet
						Alt	C	Alt	C		
Telon® Red BN 02	GG	16.76	–	3–4	3	4–5	4	4–5	4	4	4
	PAA/TG1	24.52	46.3	4	4	4	4	4–5	4–5	5	5
	PAA/TG2	25.13	49.49	4	4	5	5	5	5	5	5
	PAA/KG1	24.13	43.97	4	4	5	5	5	5	5	5
	PAA/KG2	21.23	26.67	4	3–4	5	5	5	5	5	5
Telon® Yellow RW	GG	13.48	–	3–4	4	5	4–5	4–5	4–5	4	4
	PAA/TG1	20.02	48.51	4	3–4	5	4–5	5	4–5	5	5
	PAA/TG2	22.15	64.31	4	4	5	5	5	5	5	5
	PAA/KG1	19.67	45.91	3–4	3–4	5	5	5	5	5	5
	PAA/KG2	19.01	41.02	4	3–4	5	5	5	5	5	5
Levafix® Golden Yellow BN	GG	10.63	–	3–4	3	4–5	4	4	4	5	5
	PAA/TG1	16.07	51.17	4	4	4–5	4	4–5	4–5	5	5
	PAA/TG2	18.99	78.64	4–5	4–5	5	5	5	5	5	5
	PAA/KG1	15.96	50.14	4–5	4	5	5	5	5	5	5
	PAA/KG2	14.55	36.87	4–5	4–5	5	5	5	5	5	5
Realan® Red G	GG	8.41	–	3–4	3–4	4–5	4	4–5	4–5	5	5
	PAA/TG1	24.01	185.4	4–5	4	4–5	4–5	5	4–5	5	5
	PAA/TG2	24.21	187.8	4–5	4–5	5	5	5	5	5	5
	PAA/KG1	12.71	51.12	4	4	5	5	5	5	5	5
	PAA/KG2	9.89	17.59	4–5	4–5	5	5	5	5	5	5

Printing paste composition: thickening agent 7.5% (75 g/kg paste); reactive dye (30 g/kg paste); urea (50 g/kg paste); citric acid (10 g/kg paste); drying at 85 °C/5 min; steaming at 105 °C for 30 min, followed by soaping at 90 °C/15 min in presence of (2 g/l) nonionic wetting agent. *K*/*S*: depth of shade; WF: wash fastness; PF: perspiration fastness; RF: rubbing fastness; Alt.: alteration; C: staining on white cotton.

ening agent in reactive printing of the aforementioned substrates gives higher thickening efficiency as well as better depth and fastness properties of prints in comparison with the guar gum, GG, thickener.

5. Conclusions

This research focused on application of new thickening agents, based on polymerization adducts of acrylic acid with karaya gum or tamarind seed gum, in printing of wool, silk and nylon-6 fabrics with reactive dyes. On the basis of the experimental results, we concluded the following:

- Increasing the thickening agent, PAA/TG2, concentration up to 7.5% (w/w), urea concentration up to 50 g/kg paste, citric acid concentration up to 10 g/kg paste and/or the reactive dye concentration up to 30 g/kg paste results in an enhancement in the depth of the obtained prints.

- Steam fixation at 105 °C for 30 min was found to be effective for attaining higher depth of reactive prints.
- Printability of the used substrates with reactive dyes under investigation is governed by the nature of the substrate, and follows the decreasing order: wool > Nylon-6 > Silk, regardless of the used thickening agent.
- Printing efficiency is governed by the performance of the thickening agent and follows the descending order: PAA/TG2 > PAA/TG1 > PAA/KG1 > PAA/KG2 > GG.
- The *K*/*S* values as well as the fastness properties of the obtained prints depend on the type of reactive dye.
- Optimal printing properties, i.e. higher depth along with better fastness ratings, were obtained by using a printing paste containing PAA/TG2 (7.5%, w/w), reactive dye (30 g/kg), urea (50 g/kg), critic acid (10 g/kg), followed by drying at 85 °C for 5 min and steam fixation at 105 °C for 30 min.

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