Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Using Sodium Alginate Extracted from Egyptian Algae as a Thickener in Cotton Printing with Reactive Dyes

Mohamed M. El-Molla

mohamedelmolla212@gmail.com

National Research Centre

Amera A. Rageb

National Research Centre

Madeha A. El-Kashouti

National Research Centre

Article

Keywords: Cotton Printing, Extracted, Egyptian Algae, Reactive Dyes, Sodium Alginate, Thickener, Utilization

Posted Date: November 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11503116/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Using Sodium Alginate Extracted from Egyptian Algae as a Thickener in Cotton Printing with Reactive Dyes

Mohamed M. El-Molla[1]*, Amera A. Rageb[1], & Madeha A. El-Kashouti[1]
[1]Textile Research and Technology Institute, National Research Centre, 33 El Buhouth Street, P.O. Box 12622, Cairo, Egypt.

Abstract

Printing plays a pivotal role in textile coloration, and thickeners are equally crucial in ensuring successful textile printing outcomes. This research aimed to evaluate the effectiveness of sodium alginate extracted from Egyptian brown algae—offering either high viscosity (2.5%) or low viscosity (8%)—as a thickener for printing cotton fabrics with reactive dyes. The investigation utilized flat screen-printing techniques to compare cotton fabrics printed using the extracted sodium alginate samples against those printed with commercially available sodium alginate. Key performance metrics such as color strength, fabric handle, and color fastness properties (including washing, rubbing, and perspiration fastness) were assessed. Results indicated that the rubbing fastness (both wet and dry) of fabrics printed with extracted alginate closely mirrored that of fabrics printed with commercial sodium alginate, exhibiting values ranging from good to very good. Washing fastness scores ranged from very good to excellent for staining and reached excellent levels for alteration, except for samples printed with Cibacron Blue Brilliant BR-P, which showed very good and excellent ratings for staining and alteration respectively. Perspiration fastness results, assessed under acidic and alkaline conditions, consistently ranged between very good and excellent. Further analysis of the printing pastes—prepared with both commercial and extracted sodium alginate of varying viscosities—revealed their pseudoplastic, non-Newtonian behavior. Increasing the shear rate from 2.18 to 137.1 sec^{-1} led to a notable decrease in apparent viscosity across all tested pastes, irrespective of the nature of the thickening agent or the type of reactive dye used. In conclusion, after comparing all test results, it was evident that fabrics printed with the extracted sodium alginate outperformed those printed with commercial alginate in terms of overall properties.

Keywords: Cotton Printing, Extracted, Egyptian Algae, Reactive Dyes, Sodium Alginate, Thickener, Utilization.

*All correspondence should be addressed to Prof. Dr. Mohamed M. El-Molla.
Email: mohamedelmolla212@gmail.com. mm.elmolla@nrc.sci.eg

1. Introduction

The absence of any reaction between sodium alginate and reactive dyes or cellulosic fibers makes it the most suitable thickener for use with these dyes [1-6]. The observation that sodium alginate remains unreactive with reactive dyes has often been cited as evidence that the secondary hydroxyl groups in cellulose do not participate in reactions with these dyes. However, studies involving the dyeing of oxidatively degraded cellulose suggest that both primary and secondary hydroxyl groups are indeed involved in the reaction process[7]. The reason behind sodium alginate's non-reactivity towards reactive dyes is not entirely clear, but it likely relates to the ionized groups present in the alginate. It's believed that this product's effectiveness is due to the carboxyl groups in the polymer, which ionize and repel dye ions with similar charges, thereby hindering a reaction. This repulsion effect also aids in transferring the dye from the thickener into the cellulose. In certain cases, alginate provides a superior color transfer from paste to fabric compared to other substances, a result attributed to the negative charge on the alginate ion[8]. This section examines the feasibility of utilizing sodium alginate extracted from Egyptian brown algae[9] as a thickener for cotton fabric printing with reactive dyes. Printing pastes were prepared using various classes of reactive dyes and thickened with the extracted sodium alginate samples, which were then applied to cotton fabrics through the screen-printing method. For comparison, an additional set of printing pastes thickened with commercial sodium alginate samples, which possessed similar viscosities, was prepared and applied to cotton fabrics using the same technique.

2. Experimental

2.1. Materials

2.1.1. Cotton fabric.

Cotton fabric provided by Misr Helwan for Spinning and Weaving Co. in Cairo was utilized. This fabric has specific characteristics: it weighs 138.5 grams per square meter, and there are 30 warp yarns and 28 weft yarns per centimeter. The fabric features a plain 1/1 weaving structure. It underwent desizing, kier boiling, bleaching, and mercerization, followed by washing and drying processes.

2.1.2. Dyestuffs.

-Levafix Brilliant Red P-B was generously provided by Bayer AG, West Germany, featuring a reactive center of methyl sulphonyl chloromethyl pyrimidine.

- Cibacron Blue Brilliant BR-P was supplied by Ciba-Geigy, Switzerland, with a reactive moiety of mono chlorotriazine.

-Remazol Brilliant Red 6B was provided by Hoechst, West Germany, characterized by a reactive moiety of vinyl-sulphone.

-Procion Blue SP-3R Grains were supplied by I.C.I., England, incorporating a reactive moiety of di chlorotriazine.

2.1.3. Thickeners.

-Commercial sodium alginate with low viscosity, produced by Société Française des Colloïdes (SFC) in France, was generously provided under the trade name Alginate TBVV/N2.

-Commercial sodium alginate with high viscosity, manufactured by C.E.C.A. Co., France, was kindly supplied under the trade name Cecalginate HV/600.

- Laboratory-extracted sodium alginates were prepared in both low and high viscosity variants[9].

2.1.4. Chemicals.

Sodium bicarbonate and sodium carbonate of laboratory grade chemicals and nonionic detergent were used.

2.2. Methods.

2.2.1. Preparation of printing pastes.

Using the aforementioned series of reactive dyes, printing pastes thickened with commercial & extracted sodium alginate, were prepared according to the following recipe.

Ingredients	Thickener pastes (g)
Dye	40
Urea	100
Ludigol	10
Calgon T	5
Sodium bicarbonate	X
Thickener	Y
Water	Z
Total weight	100

Where: X = The amount of sodium bicarbonate used was varied according to the nature of the reactive dye used as follows:

20 g/kg on using Levafix Brilliant Red P-B, 20 g/kg on using Procion Blue SP-3R, 30 g/kg on using Cibacron Blue Brilliant BR-P, 30 g/kg on using Remazol Brilliant Red 6B.

Y = The amount of thickener used was 80 and 25 g/kg in case of low & high viscosity sodium alginate, respectively, for both the extracted and commercial samples.

Sodium alginate samples were soaked in small quantities of water overnight at room temperature in preparation for the printing pastes. The dye was initially mixed with urea and a portion of hot distilled water. This mixture was then thoroughly stirred to achieve a homogeneous solution. Next, this solution was added to the thickener suspension, and the entire mixture was vigorously stirred while bicarbonate was incorporated. Finally, the total weight of the paste was adjusted to one kilogram by adding the requisite amount of distilled water.

2.2.2. Printing Technique.

All the printing pastes were applied to the cotton fabric through flat screen.

2.2.3. Fixation.

Fixation of the printed goods was done either by steaming or thermofixation as follows:

a- Steaming.

Steam fixation for all printed fabrics was done at 100–103 °C for 10 minutes.

b- Thermofixation.

Thermofixation was carried out using an automatic thermostatic oven from Werner Mathis Co., Switzerland. The fixation time and temperature varied depending on the type of reactive dye used. Fabrics printed with Levafix Brilliant Red P-B were fixed at 150 °C for 45 seconds. Those with Cibacron Blue Brilliant BR-P required fixation at 150 °C for 3.5 minutes. For fabrics printed with Procion Blue SP-3R, the fixation was done at 145 °C for 3.5 minutes, whereas those printed with Remazol Brilliant Red 6B were fixed at 145 °C for 4 minutes.

2.2.4. Washing.

The washing process for the fixed printed goods involved five stages: First, a thorough rinse with cold water. Next, treatment with hot water, followed by exposure to near-boiling temperatures (90–95 °C) with a solution containing 2 g/l of nonionic detergent. After that, they were washed with hot water and then rinsed again with cold water. Finally, the samples were dried and evaluated for color strength and overall fastness properties.

2.3. Analysis and Measurements.

2.3.1. Rheological Measurements

The rheological properties and apparent viscosity of the pure thickener at a 3% concentration were analyzed using a Rheomat-15 rotary viscometer (Zurich, Switzerland). The measurements were conducted under specific conditions. Initially, the shearing stress was recorded incrementally as the shear rate increased in an upward direction. Each measurement of the shearing stress was taken after a shear time of 60 seconds at the respective shear rate. Subsequently, the shearing stress of the same sample was measured again, this time while progressively reducing the shear rate from its maximum value back to the starting point (downward direction). The apparent viscosity was determined using the following equation (1) [10].

$$\eta = \tau/D \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: η = apparent viscosity [poise], τ = shearing stress [dyne/cm^2] , D = rate of shear [S^{-1}]

2.3.2. Color Measurements.

The color yield (K/S) [11],of the printed goods was evaluated by light reflectance technique at the maximum wave length. The spectrophotometer used was of model ICS-Texicon Limited, Kennetside Park, Newbury, Berkshire RG 14 5TE, England.

This spectrophotometer is a precision instrument designed to provide extremely fast and accurate measurement, and an extremely high degree of short and long-term stability.

2.3.3. Fastness Properties

Fastness to washing, rubbing, and perspiration was assessed according to standard methods[12-14].

3. Results and Discussion

Both extracted and commercially available sodium alginates are utilized due to their identical structures and functional groups. The primary difference lies in the length of the polymer chain, which influences viscosity—ranging from high to low—and thus determines the required concentration. As stated earlier, the main objective here is to assess the efficacy of sodium alginate samples sourced from Egyptian brown algae as thickeners for cotton fabric printing using reactive dyes. To this end, several types of reactive dyes were chosen, including Levafix Brilliant Red P-B, Cibacron Blue Brilliant BR-P, Procion Blue SP-3R, and Remazol Brilliant Red 6B. Printing pastes were formulated with both commercial and extracted sodium alginate of varying viscosities, incorporating the aforementioned reactive dyes. Cotton fabric samples were individually screen printed using these pastes both immediately after preparation and after two and seven days of storage. Once dried, the printed materials were fixed through either steaming or thermofixation, then thoroughly washed, dried, and evaluated for color strength and overall fastness properties.

3.1.Color strength:

Table 1 presents the color strength, expressed as K/S, of the printed samples. The data indicates that the color strength is influenced by both the type of reactive dye used and the fixation method. When commercial alginate (8%) is employed for all dyes, samples printed and fixed by steaming exhibit higher K/S values compared to those fixed by thermofixation. Conversely, using extracted alginate (8%) with Levafix Brilliant Red P-B shows the opposite trend. With commercial sodium alginate (2.5%), samples printed and fixed by thermofixation have higher K/S values than those fixed by steaming when using Remazol Brilliant Red 6B and Procion Blue SP-3R. However, Levafix Brilliant Red P-B yields different results. For Cibacron Blue Brilliant BR-P, equal K/S values are observed regardless of whether steaming or thermofixation is used. This pattern is consistent when using extracted sodium alginate (2.5%).

These variations may result from differences in the reactive dyes' functional reactive groups, molecular size, configuration, and substituents. Table 1 also demonstrates that samples printed with high viscosity extracted alginate (2.5%) show higher K/S values than those printed with commercial alginate of the same viscosity, regardless of the dye type, fixation method, or storage time before printing. Similarly, using low viscosity extracted alginate (8%) results in higher K/S values than commercial alginate of low viscosity (8%) for all dye series, except for samples with Levafix Brilliant Red P-B and Cibacron Blue Brilliant BR-P fixed by steaming. The superior performance of extracted alginate as a thickener likely stems from its higher purity compared to commercial samples, which may contain additives.

Additionally, Table 1 reveals that storing printing pastes for two days generally leads to a slight increase in K/S values, while storing for seven days results in a slight increase or decrease depending on the thickening agent type, reactive dye nature, and fixation method. The K/S increase after two days might be due to enhanced swellability of the thickeners, leading to greater homogeneity in the printing pastes. The decrease upon storing for seven days could be attributed to the hydrolysis of reactive dyes caused by the alkali in the printing paste. The extent of this decrease varies with the type of reactive dye used.

Table 1. Color strength of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	Type of fixation	Color strength (K/S) on using											
		Commercial alginate 8%*			Extracted alginate 8%*			Commercial alginate 2.5%**			Extracted alginate 2.5%**		
		I	II	III	I	II	III	I	II	III	I	II	III
Levafix Brilliant Red P-B	Steaming #	24.0	24.6	24.5	23.1	24.5	23.8	24.3	25.8	24.7	25.6	26	25.8
	Thermofixation At 150 ^{0}C for 45 Sec.	20.5	21.5	20.3	24.4	25	23.3	23.8	24.3	23.7	26	26.4	25.8
Cibacron Blue Brilliant BR-P	Steaming #	14.1	14.4	14.8	13.2	14.1	14.6	12.9	13	14.9	14.8	15.9	16.8
	Thermofixation At 150 ^{0}C for 3.5min.	10.5	10.8	11.3	12.7	12.8	14.2	12.2	13.6	14.9	13.9	15.5	17.1
Procion Blue SP-3R	Steaming #	9.17	9.4	9.8	10.5	10.6	11.2	9.2	10.1	10.3	9.3	10.4	10.8
	Thermofixation At 145 ^{0}C for 3.5 min.	8.7	9.3	9.7	10.5	12.0	12.2	10.6	11.7	12	12.7	13.6	13.8
Remazol Brilliant Red 6B	Steaming #	13.3	16.3	16.3	16.1	17.1	16.4	9.7	10.9	10.7	12.2	13.2	12.7
	Thermofixation At 145 ^{0}C for 4 min.	9.7	10.3	9.2	14.9	15	14.2	12.9	13.2	13.1	13.9	15.1	14.9

I. Freshly prepared pastes # Steaming was carried out at 100-103 ^{0}C for 10 minutes

II. Stored for two days * Low viscosity sodium alginate sample

III. Stored for seven days ** High viscosity sodium alginate sample

3.2. Handle:

In the realm of textile printing, the handle of printed goods ranks among the most crucial properties. Table 2 provides an evaluation of the handle of cotton fabrics printed with the specified printing pastes. It becomes evident from this table that cotton fabrics, printed using the previously mentioned thickening agents—either commercial sodium alginates or those extracted—retain a soft handle both before and after being stored for two or seven days. The soft handle observed in these printed goods suggests that there is no chemical interaction between the sodium alginate and the reactive dye used. This aligns with previous studies and

underscores the suitability of the extracted samples as thickeners in printing cotton fabrics with various types of reactive dyes.

Table 2. Handle of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	Type of fixation	Handle of cotton fabrics printed with reactive dyes on using											
		Commercial alginate 8%*			Extracted alginate 8%*			Commercial alginate 2.5%**			Extracted alginate 2.5%**		
		I	II	III	I	II	III	I	II	III	I	II	III
Levafix Brilliant Red P-B	Steaming #	S	S	S	S	S	S	S	S	S	S	S	S
	Thermofixation At 150 ^{0}C for 45 Sec.	S	S	S	S	S	S	S	S	S	S	S	S
Cibacron Blue Brilliant BR-P	Steaming #	S	S	S	S	S	S	S	S	S	S	S	S
	Thermofixation At 150 ^{0}C for 3.5min.	S	S	S	S	S	S	S	S	S	S	S	S
Procion Blue SP-3R	Steaming #	S	S	S	S	S	S	S	S	S	S	S	S
	Thermofixation At 145 ^{0}C for 3.5 min.	S	S	S	S	S	S	S	S	S	S	S	S
Remazol Brilliant Red 6B	Steaming #	S	S	S	S	S	S	S	S	S	S	S	S
	Thermofixation At 145 ^{0}C for 4 min.	S	S	S	S	S	S	S	S	S	S	S	S

I. Freshly prepared pastes # Steaming was carried out at 100-103 ^{0}C for 10 minutes

II. Stored for two days * Low viscosity sodium alginate sample S = Soft

III. Stored for seven days ** High viscosity sodium alginate sample

3.3.Fastness to rubbing:

Another important property in the field of textile printing is the fastness of the color to rubbing. Table 3 shows the fastness to wet and dry rubbing of cotton fabric samples printed with the aforementioned printing pastes.

Table 3. Rubbing fastness properties of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	Type of fixation	Color fastness to rubbing on using															
		Commercial alginate 8%*				Extracted alginate 8%*				Commercial alginate 2.5%**				Extracted alginate 2.5%**			
		I		II		I		II		I		II		I		II	
		Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Levafix Brilliant Red P-B	Steaming #	3	4	3	3	3	3-4	3	3	3	3	3	3	3	3	3	3
	Thermofixation At 150 ^{0}C for 45 Sec.	3	3-4	3	3	3	3-4	3	3	3	3	3	3	3	3	3	3
Cibacron Blue Brilliant BR-P	Steaming #	3-4	4	3	3	3	3	3	3	3	3	3	3-4	3	3	3	3
	Thermofixation At 150 ^{0}C for 3.5min.	3-4	4	3	3-4	3	3-4	3	3	3-4	3-4	3	3	3-4	3-4	3	3
Procion Blue SP-3R	Steaming #	3	3-4	3	3	3	3	3	3	3	3	3	3-4	3	3	3	3
	Thermofixation At 145 ^{0}C for 3.5 min.	3-4	3-4	3	3	3	3-4	3	3	3	3-4	2-3	3	3	3-4	2-3	3
Remazol Brilliant Red 6B	Steaming #	3	3-4	2-3	3	3	3	2-3	3	3	3-4	3	3	3	3-4	3	3-4
	Thermofixation At 145 ^{0}C for 4 min.	3	3-4	3	3	3	3-4	3	3	3	3-4	3	3	3	3	3	3

I. Freshly prepared pastes

II. Stored for two days

Steaming was carried out at 100-103 ^{0}C for 10 minutes

* Low viscosity sodium alginate sample

** High viscosity sodium alginate sample

The data in Table 3 indicates a slight variation in the rubbing fastness properties of the printed goods, which appear to depend on the specific reactive dye used. This variation can likely be attributed to differences in the solubility and reactivity of these dyes, as previously discussed. Additionally, Table 3 demonstrates that the rubbing fastness properties, whether wet or dry, of samples printed with the extracted alginate are nearly identical to those of samples printed with commercial sodium alginate. The fastness values for both sets of samples range from good to very good.

3.4. Fastness to washing:

The washing fastness properties of cotton fabric samples, "printed using different types of reactive dyes and thickened with commercial or extracted alginate samples" and carried out at 60 and 95 °C, are given in Tables (4 and 5) respectively.

Table 4. Washing fastness properties at 60 ^{0}C of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	Type of fixation	Color fastness to washing on using															
		Commercial alginate 8%*				Extracted alginate 8%*				Commercial alginate 2.5%**				Extracted alginate 2.5%**			
		I		II		I		II		I		II		I		II	
		St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.
Levafix Brilliant Red P-B	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 150 ^{0}C for 45 Sec.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Cibacron Blue Brilliant BR-P	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 150 ^{0}C for 3.5min.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
Procion Blue SP-3R	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 145 ^{0}C for 3.5 min.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Remazol Brilliant Red 6B	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 145 ^{0}C for 4 min.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5

I. Freshly prepared pastes # Steaming was carried out at 100-103 ^{0}C for 10 minutes

II. Stored for two days * Low viscosity sodium alginate sample

** High viscosity sodium alginate sample

St.= Staining. Alt. = Alteration

Table 5. Washing fastness properties at 95 ^{0}C of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	Type of fixation	Color fastness to washing on using															
		Commercial alginate 8%*				Extracted alginate 8%*				Commercial alginate 2.5%**				Extracted alginate 2.5%**			
		I		II		I		II		I		II		I		II	
		St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.
Levafix Brilliant Red P-B	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 150 ^{0}C for 45 Sec.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Cibacron Blue Brilliant BR-P	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 150 ^{0}C for 3.5min.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
Procion Blue SP-3R	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 145 ^{0}C for 3.5 min.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Remazol Brilliant Red 6B	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 145 ^{0}C for 4 min.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5

I. Freshly prepared pastes # Steaming was carried out at 100-103 ^{0}C for 10 minutes

II. Stored for two days * Low viscosity sodium alginate sample

** High viscosity sodium alginate sample

St.= Staining. Alt. = Alteration

The data in Tables 4 and 5 clearly show that the washing fastness properties depend on the type of reactive dye used, while the fixation method has little impact on these properties. The washing fastness results range from very good to excellent for staining and are excellent for alteration. This is consistent across all the series of reactive dyes mentioned, except for samples printed with Cibacron Blue Brilliant BR-P, which achieve very good and excellent ratings for staining and alteration, respectively.

3.5. Fastness to perspiration:

The data in Tables 6 and 7 clearly demonstrate that the color fastness properties to both acidic and alkaline perspiration for goods printed with extracted sodium alginate closely match those printed with commercial

alginates. This observation is consistent across all types of reactive dyes and fixation methods. Additionally, storing the applied pastes seems to have little to no impact on the color fastness properties regarding perspiration. Generally, the color fastness values range from very good to excellent for both acidic and alkaline conditions. Consequently, sodium alginate samples, whether low or high viscosity, extracted from Egyptian brown algae, appear to be suitable as thickeners for printing cotton fabrics with reactive dyes. The color strength and fastness properties to rubbing, washing, and perspiration for goods printed with these extracted sodium alginates are nearly equivalent to those of samples printed with commercial sodium alginates.

Table 6. Acidic perspiration fastness properties of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	**Type of fixation**	**Acidic perspiration fastness properties on using**															
		Commercial alginate 8%*				**Extracted alginate 8%***				**Commercial alginate 2.5%****				**Extracted alginate 2.5%****			
		I		**II**		**I**		**II**		**I**		**II**		**I**		**II**	
		St.	**Alt.**	**St.**	**Alt.**	**St.**	**Alt.**	**St.**	**Alt.**	**St.**	**Alt.**	**St.**	**Alt.**	**St.**	**Alt.**	**St.**	**Alt.**
Levafix Brilliant Red P-B	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 150 ^{0}C for 45 Sec.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Cibacron Blue Brilliant BR-P	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 150 ^{0}C for 3.5min.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Procion Blue SP-3R	Steaming #	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
	Thermofixation At 145 ^{0}C for 3.5 min.	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5	4-5	5
Remazol Brilliant Red 6B	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 145 ^{0}C for 4 min.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5

I. Freshly prepared pastes # Steaming was carried out at 100-103 ^{0}C for 10 minutes

II. Stored for two days * Low viscosity sodium alginate sample

** High viscosity sodium alginate sample

St.= Staining. Alt. = Alteration

Table 7. Alkaline perspiration fastness properties of cotton fabrics printed with reactive dyes using the extracted & commercial sodium alginate as thickener

Dye used	Type of fixation	Alkaline perspiration fastness properties on using															
		Commercial alginate 8%*				Extracted alginate 8%*				Commercial alginate 2.5%**				Extracted alginate 2.5%**			
		I		II		I		II		I		II		I		II	
		St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.	St.	Alt.
Levafix Brilliant Red P-B	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 150 ^{0}C for 45 Sec.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
Cibacron Blue Brilliant BR-P	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 150 ^{0}C for 3.5min.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
Procion Blue SP-3R	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 145 ^{0}C for 3.5 min.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
Remazol Brilliant Red 6B	Steaming #	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5
	Thermofixation At 145 ^{0}C for 4 min.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5

I. Freshly prepared pastes # Steaming was carried out at 100-103 ^{0}C for 10 minutes

II. Stored for two days * Low viscosity sodium alginate sample

** High viscosity sodium alginate sample

St.= Staining. Alt. = Alteration

3.6. Rheological properties:

The rheological properties of printing pastes, particularly their viscosity, play a crucial role in managing dye penetration, color depth, print sharpness, and evenness. With this understanding, it's essential to delve into the rheological properties of these printing pastes. For this research, a variety of printing pastes were prepared using Levafix Brilliant Red P-B, Cibacron Blue Brilliant BR-P, Procion Blue SP-3R, and Remazol Brilliant Red 6B. These pastes were thickened with either commercial or extracted sodium alginates with low and high viscosities. The rheological characteristics of these pastes were examined using a Co-axial

cylinder rheometer at 25 °C. Shear rates were gradually increased by boosting the rotational speed, and the corresponding shearing stresses were measured. The shearing stress was also recorded when the rotational speed was decreased. This method enabled the creation of experimental rheograms (both up and down flow curves). The findings are depicted in Figures 1 to 4.

Figure 1 . Rheograms of the printing pastes contaning Levafix Brilliant Red P-B and thickened with extracted and commercial sodium alginate samples

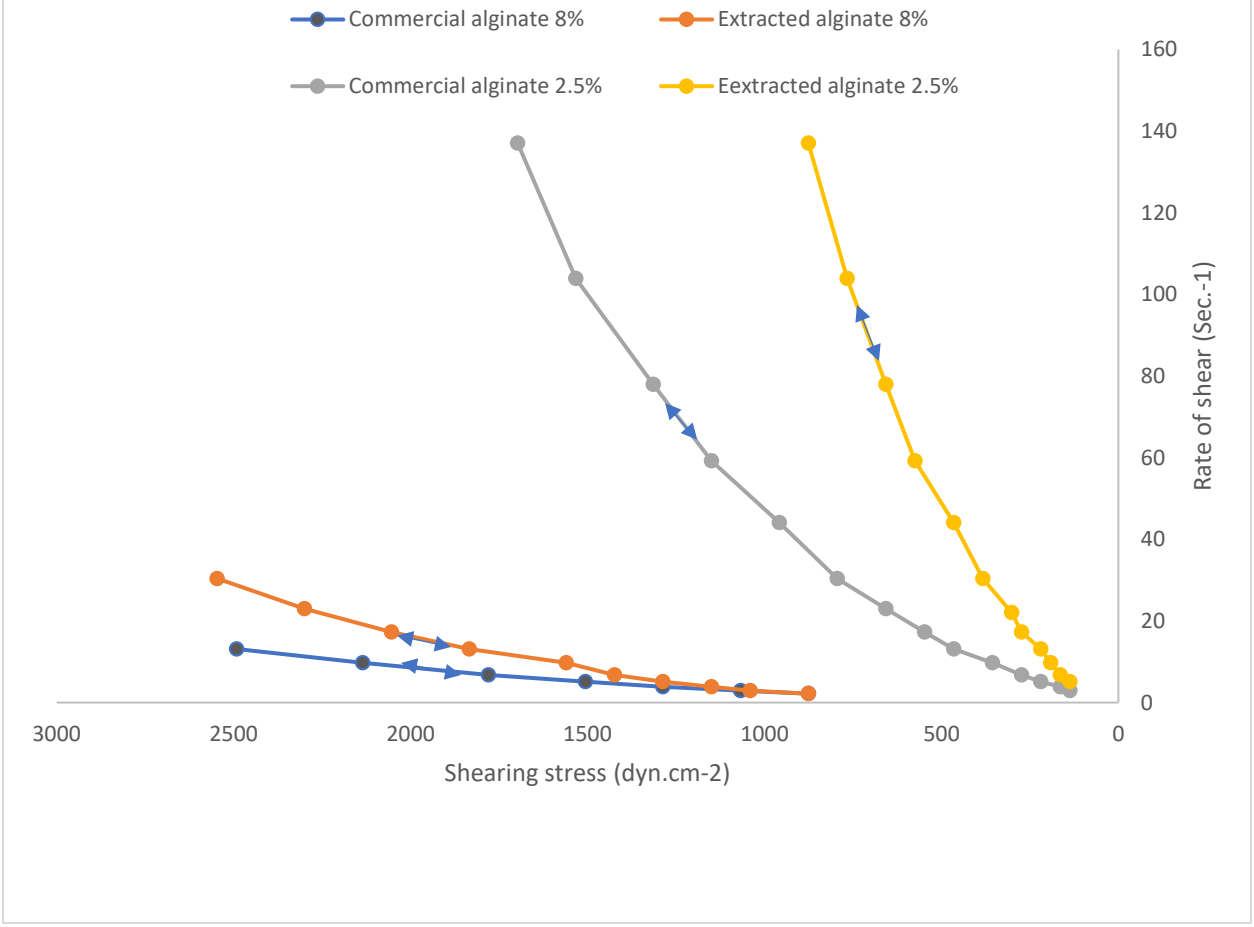


Figure 2 . Rheograms of the printing pastes Cibacron Blue Brilliant BR-P and thickened with extracted and commercial sodium alginate samples

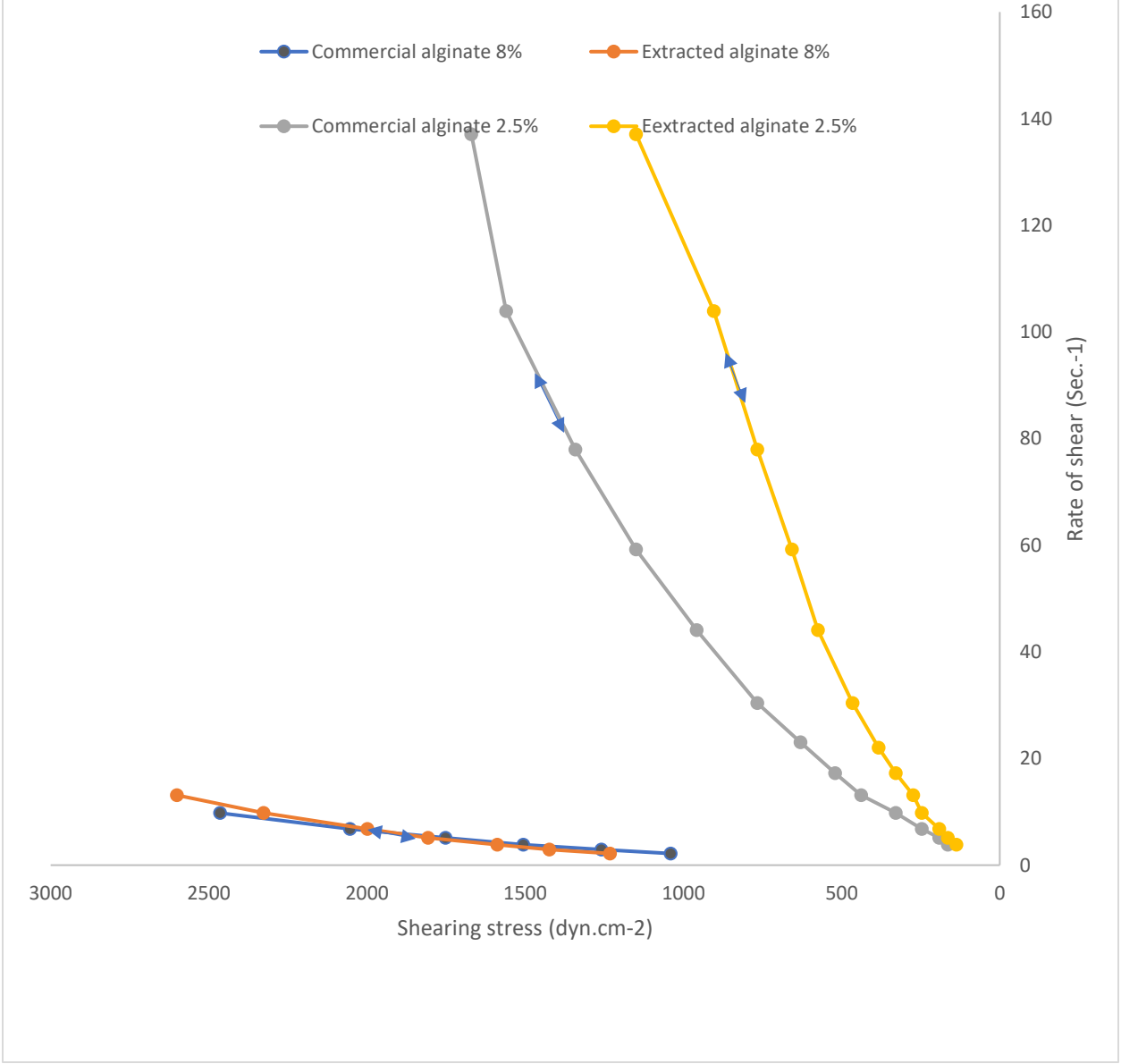


Figure 3 . Rheograms of the printing pastes Procion Blue SP-3Rand thickened with extracted and commercial sodium alginate samples

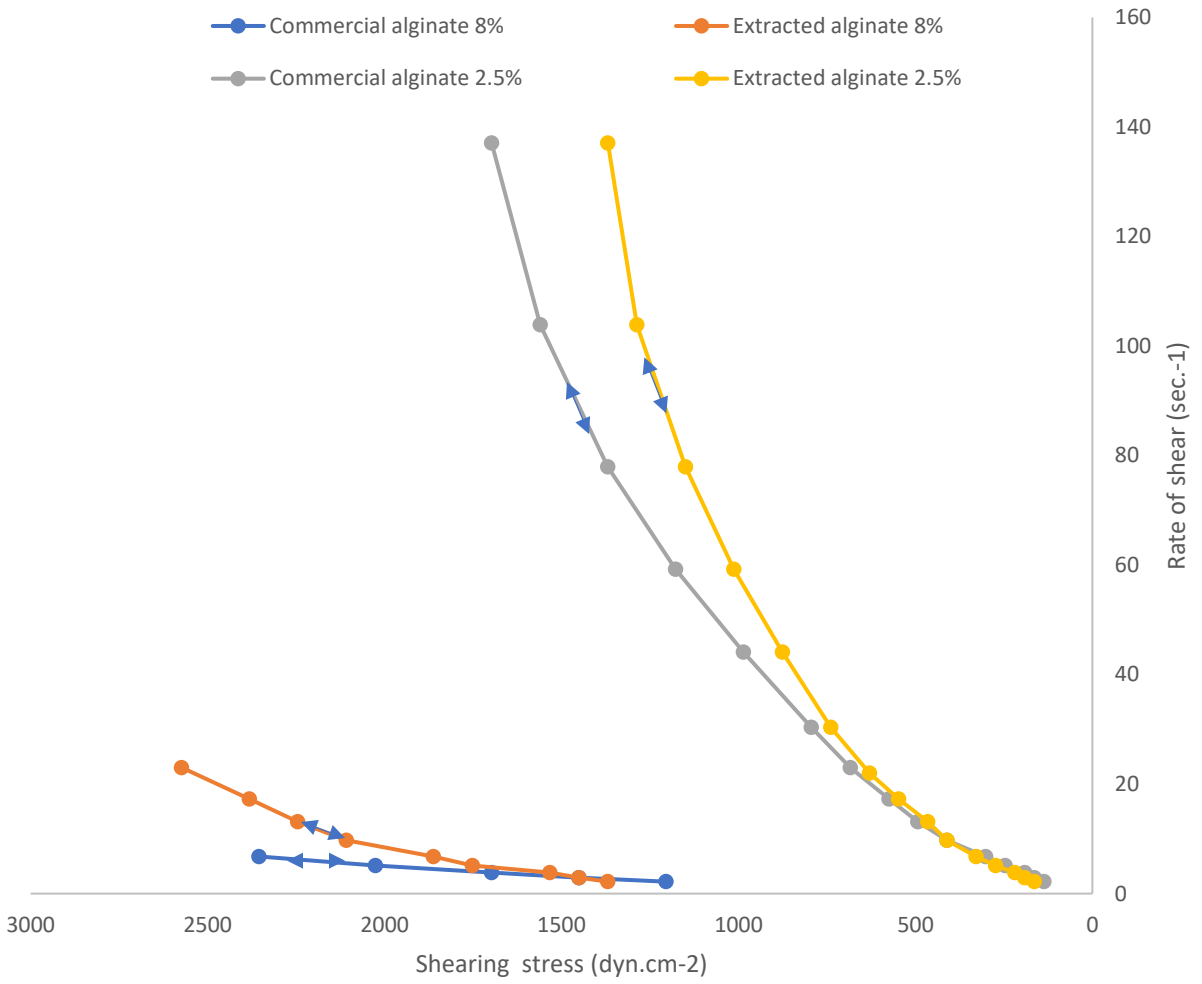
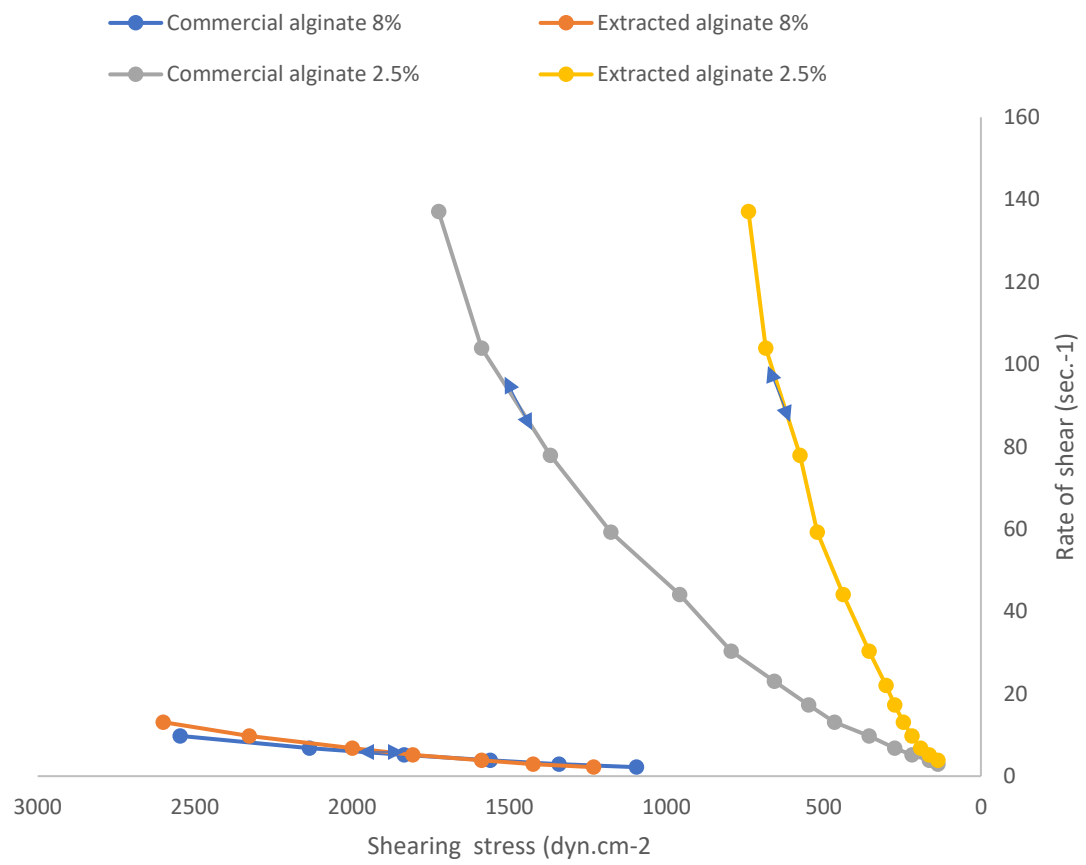


Figure 4 . Rheograms of the printing pastes Remazol Brilliant Red 6B and thickened with extracted and commercial sodium alginate samples



It is clear from Figures (1-4) that printing pastes thickened with either commercial and/or extracted sodium alginates of low and high viscosities are characterized by non-Newtonian pseudoplastic behavior, where the up and down flow curves are coincident [15]. It is clear from Figures (1-4) that, the location of the rheograms with respect to the rate of shear axis varies according to the nature of the thickening agent used and / or the reactive dye in the printing paste, which indicates a variation in the apparent viscosity. A clearer picture about the dependence of the apparent viscosity on the rate of shear, nature of the thickening agent used and on the kind of the reactive dye is clear from Tables (8-11).

Table8: Effect of the nature of the bleaching agent on the apparent viscosity of printing pastes thickened with extracted and commercial sodium alginate on using Levafix Brilliant Red P-B.

Rate of shear Sec^{-1}	**Apparent viscosity in Poise on using**			
	Commercial alginate 8%*	**Extracted alginate 8%***	**Commercial alginate 2.5%****	**Extracted alginate 2.5%****
2.18	401.9	401.9	-	-
2.927	365.69	356.31	46.88	-
3.851	334.16	298.61	42.66	-
5.139	293.03	250.41	42.62	26.63
6.779	262.53	210.02	40.39	24.23
9.771	218.56	159.72	36.43	19.61
13.12	189.9	139.82	35.47	16.69
17.26	-	118.97	31.72	15.86
23.03	-	99.95	28.55	13.08
30.38	-	83.81	26.14	12.62
44.1	-	-	21.73	10.55
59.22	-	-	19.42	9.71
77.92	-	-	16.86	8.43
103.9	-	-	14.57	7.38
137.1	-	-	12.38	6.4

* Low viscosity sodium alginate sample ** High viscosity sodium alginate sample.

Table9: Effect of the nature of the bleaching agent on the apparent viscosity of printing pastes thickened with extracted and commercial sodium alginate on using Cibacron Blue Brilliant BR-P

Rate of shear Sec^{-1}	**Apparent viscosity in Poise on using**			
	Commercial alginate 8%*	**Extracted alginate 8%***	**Commercial alginate 2.5%****	**Extracted alginate 2.5%****
2.18	477.26	565.18	-	-
2.927	431.32	487.58	-	-
3.851	391.04	412.37	42.66	35.55
5.139	340.89	351.64	37.29	31.97
6.779	302.92	294.84	36.35	28.27
9.771	252.19	238.18	33.63	25.22
13.12	-	198.25	33.39	20.86
17.26	-	-	30.14	19.03
23.03	-	-	27.36	16.66
30.38	-	-	25.23	15.32
44.1	-	-	21.73	13.03
59.22	-	-	19.41	11.09
77.92	-	-	17.21	9.83
103.9	-	-	15.02	8.69
137.1	-	-	12.18	7.18

* Low viscosity sodium alginate sample ** High viscosity sodium alginate sample.

Table10: Effect of the nature of the bleaching agent on the apparent viscosity of printing pastes thickened with extracted and commercial sodium alginate on using Procion Blue SP-3R

Rate of shear Sec^{-1}	**Apparent viscosity in Poise on using**			
	Commercial alginate 8%*	**Extracted alginate 8%***	**Commercial alginate 2.5%****	**Extracted alginate 2.5%****
2.18	**552.62**	**627.98**	62.79	75.35
2.927	496.96	496.96	56.26	65.63
3.851	440.81	398.15	49.76	56.87
5.139	394.26	340.98	47.95	53.27
6.779	347.34	274.64	44.42	48.46
9.771	-	215.76	42.03	42.03
13.12	-	171.12	37.56	35.47
17.26	-	138.01	33.31	31.72
23.03	-	111.85	29.74	27.36
30.38	-	-	26.13	24.33
44.1	-	-	22.35	19.86
59.22	-	-	19.88	17.1
77.92	-	-	17.57	14.75
103.9	-	-	15.02	12.38
137.1	-	-	12.38	9.98

* Low viscosity sodium alginate sample ** High viscosity sodium alginate sample.

Table11: Effect of the nature of the bleaching agent on the apparent viscosity of printing pastes thickened with extracted and commercial sodium alginate on using Remazol Brilliant Red 6B

Rate of shear Sec^{-1}	Apparent viscosity in Poise on using			
	Commercial alginate 8%*	**Extracted alginate 8%***	**Commercial alginate 2.5%****	**Extracted alginate 2.5%****
2.18	**502.38**	**565.16**	-	-
2.927	459.45	487.58	46.88	-
3.851	405.26	412.47	42.66	35.54
5.139	356.26	351.64	42.62	31.98
6.779	315.03	294.84	40.39	28.27
9.771	260.6	238.18	36.43	22.42
13.12	-	198.25	35.47	18.78
17.26	-	-	31.72	15.86
23.03	-	-	28.55	13.09
30.38	-	-	26.14	11.72
44.1	-	-	21.73	9.93
59.22	-	-	19.88	8.78
77.92	-	-	17.57	7.38
103.9	-	-	15.28	6.59
137.1	-	-	12.58	5.4

* Low viscosity sodium alginate sample ** High viscosity sodium alginate sample.

The data presented in Tables 8-11 clearly demonstrate that increasing the applied shear rate from 2.18 to 137.1 sec^{-1} typically results in a notable reduction in apparent viscosity. This trend is observed consistently across all tested printing pastes, regardless of the specific thickening agents or the reactive dyes used. Moreover, the data indicate that at a constant shear rate, the apparent viscosities of two laboratory-prepared variants derived from Egyptian brown algae—characterized by high and low viscosities—are nearly equivalent to their commercial sodium alginate counterparts. For example, printing pastes containing Procion Blue SP-3R and thickened with commercial sodium alginate exhibit apparent viscosities of 496.96 and 56.26 poise at a shear rate of 2.927 sec^{-1}, while those thickened with lab-prepared alginates demonstrate viscosities of 496.96 and 65.63 poise under the same conditions. Additionally, the type of reactive dye influences the apparent viscosity of the printing paste. At a shear rate of 5.139 sec^{-1}, the commercial sodium

alginate of low viscosity shows viscosities of 293.03, 340.98, 394.26, and 356.26 poise when using dyes like Levafix Brilliant Red P-B, Cibacron Blue Brilliant BR-P, Procion Blue SP-3R, and Remazol Brilliant Red 6B, respectively. In contrast, the extracted low viscosity sodium alginate results in values of 250.41, 351.64, 340.98, and 351.64 poise for the same dyes. On the other hand, for high-viscosity commercial sodium alginate, the viscosities are 42.62, 37.29, 47.95, and 42.62 poise, whereas the extracted versions yield 26.63, 31.97, 53.27, and 31.98 poise with these dyes. These variations in apparent viscosities might be attributed to differences in functional groups, molecular size, configuration, and substituents among the reactive dye series mentioned.

4. Conclusion

The K/S values for samples printed using extracted high-viscosity alginate (2.5%) are consistently higher compared to those printed with commercial high-viscosity alginate (2.5%) as a thickener. This observation remains valid irrespective of the reactive dye type, fixation method, or storage duration prior to printing. Similarly, samples printed with extracted low-viscosity alginate (8%) exhibit higher K/S values than those printed with commercial low-viscosity alginate (8%) under the same conditions. However, an exception is noted for samples printed using Levafix Brilliant Red P-B and Cibacron Blue Brilliant BR-P, which were fixed by steaming. Storage of printing pastes for two days generally results in a slight increase in K/S values, whereas storage for seven days produces either a minor increase or decrease, depending on the type of thickener used, the reactive dye, and the fixation method employed for the printed goods. Cotton fabrics printed with both commercial and extracted sodium alginates, before or after storing for two or seven days, demonstrate a soft handle. The rubbing fastness, whether wet or dry, of fabrics printed with extracted alginate is almost equivalent to those printed with commercial alginate, ranging from good to very good. Washing fastness shows results from very good to excellent in terms of staining and excellent in terms of alteration for all reactive dye series tested—except for samples printed using Cibacron Blue Brilliant BR-P, which achieve very good and excellent ratings for staining and alteration, respectively. Similarly, color fastness to perspiration ranges from very good to excellent for both acidic and alkaline conditions. In conclusion, low- and high-viscosity sodium alginate extracted from Egyptian brown algae can be safely utilized as thickeners for printing cotton fabrics with reactive dyes. The color strength and fastness properties—including resistance to rubbing, washing, and perspiration—of textiles printed with these extracted sodium alginates are nearly equivalent to those printed using commercial alginates. Printing pastes formulated with either commercial or extracted sodium alginates of varying viscosities exhibit non-Newtonian pseudoplastic behavior. Higher shear rates, ranging from 2.18 to 137.1 sec^{-1}, consistently lead

to significant reductions in apparent viscosity across all examined printing pastes, regardless of thickening agent type or reactive dye used.

Acknowledgements

The authors wish to acknowledge the National Research Centre for funding and for providing chemicals and all measurements.

Declaration section

Funding for this research, including experiments, measurements, and analyses, was provided by the National Research Centre.

Data Availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Author contribution statement

Prof. Dr. Mohamed M. El-Molla and Prof. Dr. Amira A. Ragheb proposed the idea, conducted the experiments, recorded the results, and prepared and wrote the research, while Prof. Dr. Madiha A. El-Kashouti reviewed it.

References

1. V.A. Shenai . Technology of printing. Sevak Publication Bombay; 2003, 1(2):10-50.
2. S. Xiaoping; “The Application of Thickener HBJH Substituted for Sodium Alginate.” Dyeing and Finishing,1997, 7:007.
3. H. Molllet, & A. Grubenmann . Formulation Technology Emulsions, Suspensions, Solid Forms, diterjemahkan oleh Payne, HR, Willey,2001, 59-62, 177, 259-262.
4. C. R. Madhu, & M. C. Patel. Reactive Dye Printing on Cotton with Natural and Synthetic Thickeners. International Research Journal of Engineering and Technology,2016, 3, 1418-1420.
5. A. D. Broadbent. Basic principles of textile coloration (2001).
6. M. S. Abdelrahman, S. H. Nassar, H. Mashaly, S. Mahmoud, D. Maamoun, T. A. Khattab. Review in Textile Printing Technology. Egypt.J.Chem.2020, Vol. 63, No.9. pp. 3465- 3479.DOI: 10.21608/ejchem.2020.23726.2418
7. G.E. Krichevskii and F.I. Sadov; Izvest. Vysshikh Ucheb. Zavedenii-Tekhnol. Tekstil Prom. 1961, No. 3, 102-9 ; C.A., 56, 2595 h
8. R.H.M. Dowell; Reviews of Pure and Applied Chemistry, 1960,10, 1-19.
9. M. M. El-Molla, A. A. Rageb, & M. A. El-Kashouti, Extraction and Characterization of Sodium Alginate from Egyptian Algae. Sent for publication on Scientific Reports.
10. Fox, Robert; McDonald, Alan; Pritchard, Philip (2012). Fluid Mechanics (8 ed.). John Wiley & Sons. *pp. 76–83.* ISBN 978-1-118-02641-0.
11. D. B. Judd, H. Wyszecki, Color in Business, Science and Industry, 3rd ed., John Wiley & Sons, New York 1975.
12. International Organization for Standardization. Textiles—Tests for color fastness. Part X12: Color fastness to rubbing. 2021. Available at: https://www.iso.org/standard/65207.html. Accessed February 16, 2026.
13. Alemayehu T, Teklemariam Z. Application of natural dyes on textile: A review. International J of Res. Granthaalayah, 2014, 2(2):61-68.
14. Trotman, E. R. Dyeing and Chemical Technology of Textile Fibre; Griffin: London, 1970.
15. M. M. El-Molla & H. S. El-Sayad. Rheological Behavior of Sodium Alginate Solutions with Added Divalent Metal Salts and Their Use as Thickeners in Cotton Printing with Reactive Dyes". Advances in Polymer Technology, 2001, Vol. 20, No.1, 58-71. DOI: 10.1002/1098-2329(200121)20:1<58::AID-ADV1004>3.0.CO;2-3