Printing cotton fabrics with creative designs using printing pastes of different rheological properties

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Abstract

The main idea of the present study is to investigate the role of rheology in the printing process and how it affects the design lines and areas through applying two different thickeners, Sodiume alginate and Carboxymethyl cellulose, which have different rheological properties to cotton fabrics using two classes of reactive dyes. Different concentrations of these thickeners were prepared and applied to cotton fabrics using manual silk screen printing. (4%) Sodiume alginate was the best concentration to obtain high levels of K/S. Sodiume alginate has a pseudoplastic behaviour while CMC has a thixotropic one. Some Creative designs were printed using 4% Sodiume alginate through manual silk screen printing.

الملخص

تعتبر الخواص الريولوجية لعجائن الطباعة من أهم العوامل التي تؤثر في عملية الطباعة باعتبارها المسئولة عن منح العجينة اللزوجة اللازمة للحصول علي طباعة متجانسة وخطوط طباعية حادة وبالتالي فإن الهدف الرئيسي من البحث هو دراسة الخواص الريولوجية لبعض أنواع المتخنات المستخدمة في عجينة الطباعة مثل الجينات الصوديوم وكربوكسي ميثيل السليلوز وتاثيرها علي مساحات وخطوط التصميم المختلفة. تم تحضير عجائن طباعة تحتوي علي الجينات الصوديوم وكربوكسي ميثيل السليلوز بتركيزات مختلفة واستخدامها في الطباعة علي أقمشة قطنية باستخدام نوعين مختلفين من الصبغات النشطة عن طريق الطباعة بالشابلونات اليدوية. تشير نتائج البحث الحالي إلى أن أفضل تركيز لألجينات الصوديوم للحصول علي أفضل عمق لوني علي أقمشة قطنية هو (4%). كما تشير النتائج الخاصة بدراسة الخواص الريولوجية إلي أن الجينات الصوديوم من نوع الموائع البسيدوبلاستيكية الغير نيوتينية أما كربوكسي ميثيل السليلوز فهو من نوع الموائع السكسوتروبيك. تم طباعة تصميمات مبتكرة باستخدام الجينات الصوديوم عن طريق الطباعة بالشابلونات اليدوية.

أهداف البحث

الهدف الرئيسي من البحث هو دراسة الخواص الريولوجية لبعض المتخنات الغير نيوتينية المستخدمة في عجائن الطباعة مثل الجينات الصوديوم وكربوكسي ميثيل السليلوز وطباعتها علي أقمشة قطنية بالصبغات النشطة باستخدام الشابلونات

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اليدوية. أيضا طباعة تصميمات مبتكرة علي أقمشة قطنية لاستخدامها كمعلقات نسجية باستخدام الجينات الصوديوم يعتبر هدف اخر للبحث.

منهجية البحث

يعتمد البحث علي المنهج التجريبي

نتائج البحث

تشير النتائج الحالية للبحث الحالي إلي أن الجينات الصوديوم من عجائن الطباعة البسيدو بلاستيكية الغير نيوتينية وبالتالي تعطي أفضل نتائج في طباعة الملامس والخطوط الدقيقة أما كريوكسي ميثيل السليلوز فهو من نوع السكسو ترويبك وبالتالي تعطي نتائج طباعية جيدة عند استخدامها في طباعة المساحات . أفضل تركيز لألجينات الصوديوم للطباعة علي الأقمشة القطنية هو (4%).

1- Introduction

Textile printing is the most versatile and important of the methods used for introducing color and design to textile fabrics. Considered analytically it is a process of bringing together a design idea, one or more colorants, and a textile substrate, using a technique for applying the colorants with some precision.[1] This is usually achieved by applying thickened pastes containing dyes or pigments onto a fabric surface according to a given color design. [2]

Reactive dyes were initially introduced commercially for application to cellulosic fibers, and this is still their most important use. [3] Reactive dyes are commonly used for cotton printing because of their high wash fastness, brilliant color and variety of hue. [4]

The rheological behaviour of the printing paste plays a great role in the process of textile printing because it affects the amount of printing paste applied on the textile surface and consequently on the quality of the printed substrate.[5] Namely during the printing process (the action of the squeegee) the printing paste is exposed to deformation forces that change the arrangement of polymer chains in their primary cross-linked structure and thus cause a drop of viscosity and increased elasticity. [6] The rheological properties of the printing paste are closely related to the chemical structure of the thickener used, its concentration and the physico-chemical interactions with other paste components. [7]

In roller printing, it recognized that, for fine line work a thickening agent, somewhat with short flow, is required to achieve good definition and thickening agent with long flow will tend to print lines. On the other hand, when printing designs containing large areas of color, a thickener with short flow tends to give unlevel printing areas instead of spreading out uniformly over the surface of the fabric. [8] The operation in roller printing subjects the thickening agents at the moment of transfer from engraved roller to fabric to very high shearing stresses. Immediately after passage through the printing nip, these shearing stresses are greatly reduced. [9] It will be obvious therefore; that, the flow properties of the thickening agents under both high and low shearing stresses are likely to be significant in obtaining a level and well defined printed marks. [10]

The main idea of the present research is to study the rheological properties of some non-Newtonian printing thickeners as Sodiume alginate and CMC and apply different concentrations of these thickeners to cotton fabrics via flat screen printing technique using two classes of reactive dyes to study their viscosity effect on design blotches and fine lines. Printing creative designs through manual silk screen printing using Sodiume alginate thickening agent is also another objective of the present work.

2- Experimental

2-1 Materials

2-1-1 Fabric

Cotton fabric produced by Domiattex Co., Egypt. The weaving structure is plain 1/1. The weight of the square meter is 96 gm.

2-1-2 Dyestuffs

Two reactive dyes were used in this research, Remazol Brilliant Yellow and Procion Blue PX-5R produced by Dystar Co., Egypt.

2-1-3 Thickening agents

Two different types of thickeners were used, Sodiume alginate is the first one and CMC was the second. Both of thickeners brought by Oxford Co, India.

2-1-4 Chemicals and auxiliaries

Sodiume carbonate and urea produced by El Gomhoria Co., Egypt.

2-2 Technical Procedures

The process of printing can be summarized as follows:

2-2-1 Preparation of the printing paste

Cotton samples were printed according to the following formulations:

Component	Paste (g/Kg) for Remazol Brilliant Yellow	Paste (g/Kg) for Procion Blue PX-5R
Reactive Dye	30	30
Urea	]75	150
Sodium Carbonate	20	20
Thickener	X	X
Water	X	X
	1000	1000

2-2-2 Printing Technique

The prepared printing pastes were applied on cotton fabrics with reactive dye via flat screen printing technique.

2-2-3 Fixation

After drying the printed samples at room temperature, they are subjected to steam at 105°c for 10 minutes.

2-2-4 Washing-off
Washing off the fixed printed samples is carried out as follows:
-Rinsing with running cold water
-Soaping at 100^0c for 10 minutes using a non-ionic detergent.
-Rinsing with running cold water and finally air-drying.

2-3 Measurements
2-3-1 Color Strength measurement
The color yields of the printed samples were determined by using the light reflectance technique performed on a Perkin-Elmer (Lambda 3B) UV/VIS Spectrophotometer at Textile Printing, Dyeing and Finishing department, Faculty of Applied Arts, Damietta University. The color strengths, expressed as K/S values, were determined by applying the Kubelka-Mink equation as follows:

$$K/S= [(1-R)^2 /2R] - [(1-R0)^2 /2R0]$$

Where R = decimal fraction of the reflectance of the dyed fabric; Ro = decimal fraction of the reflectance of the undyed fabric; K = absorption coefficient; S = scattering coefficient. [11]

2-3-2 Rheological Measurements
Rheological measurements were carried out in the laboratory of department of textile printing, dyeing and finishing at Faculty of Applied Arts (FAA), Helwan University using a rotary viscometer (Rheomat- 15), Zurish, Switzerland).

2-3-3 Color Fastness
Fastness properties to light, washing, perspiration and rubbing were carried out at National Institute for Standards (NIS-Egypt).

3- Results and Discussion
The researcher will discuss the role of various concentrations of chemical constituents by showing their effect on K/S of printed cotton samples, the effect of printing process on tensile strength of the fabric, the rheological properties of the printing pastes and finally the color fastness properties of the printed samples.

3-1 Effect of thickener concentration
The cotton samples were printed by both Remazol and procion reactive dyes using printing pastes with different concentrations (2, 4, 6 and 8%) of two thickeners, one of them was Sodiume alginate and the other was CMC, to get different density of films. The color strength of the printed samples were measured and the results are illustrated in table (1) and figure (1) as shown:

Table (1) Effect of Sodiume alginate and CMC concentration on K/S of the printed samples for both reactive dyes

	Dye	Sodiume Alginate Conc. (%)				CMC Conc. (%)			
K/S		2	4	6	8	2	4	6	8
	Remazol Brilliant Yellow	16.02	19.67	18.67	18.02	15.00	18.93	17.73	16.02
	Procion blue PX- 5R	11.01	13.72	12.10	12.75	12.12	14.26	14.54	13.07

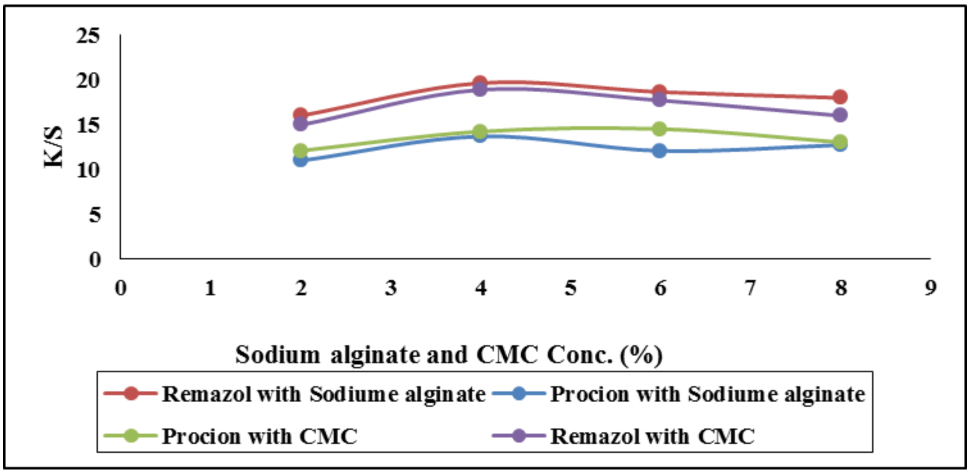

Fig (1) Effect of Sodiume alginate and CMC concentration on K/S for both reactive dyes

From the previous figure it is clear that the K/S of cotton samples printed with procion Blue PX-5R is increased by increasing both of the thickeners concentrations from 2% to 4% and 2% to 6% Sodiume alginate and CMC respectively. K/S of cotton samples printed with Remazol Brilliant Yellow reaches its maximum at 4% concentration for both thickeners. By increasing the concentration of both thickeners to 8% a gradual decrease in K/S was observed. The increase in color strength at 4% Sodiume alginate concentration for both reactive dyes, 4% and 6% CMC concentration for Remazol Brilliant Yellow and Procion Blue PX-5R respectively can be explained on the fact that: at these concentrations, the thickener is helped by other auxiliaries as (urea and carbonate) offers a suitable film on the surface of cotton fabrics, thus during steaming process maximum fixation of reactive dyes could occur. [11]

3-2 Effect of different additives

3-2-1 Effect of Urea concentration

To investigate the role of urea in printing process, Cotton samples were printed using printing pastes of 4% Sodiume Alginate for both reactive dyes, 4% CMC for Remazol Brilliant Yellow and 6% CMC for Procion Blue PX-5R with different concentrations of urea. K/S of printed samples was measured and illustrated in table (2) and Fig (2), table (3) and fig (3) for Remazol Brilliant Yellow and Procion Blue PX-5R respectively.

Table (2) Effect of Urea concentration of Sodiume alginate and CMC printing paste on K/S of Remazol Brilliant Yellow

	Urea Conc.(g/L)	Without	25	75	125	150
K/S	Remazol Brilliant Yellow with Sodiume alginate	19.42	19.50	19.67	21.53	20.75
	Remazol Brilliant Yellow with CMC	16.80	19.61	19.75	21.03	19.33

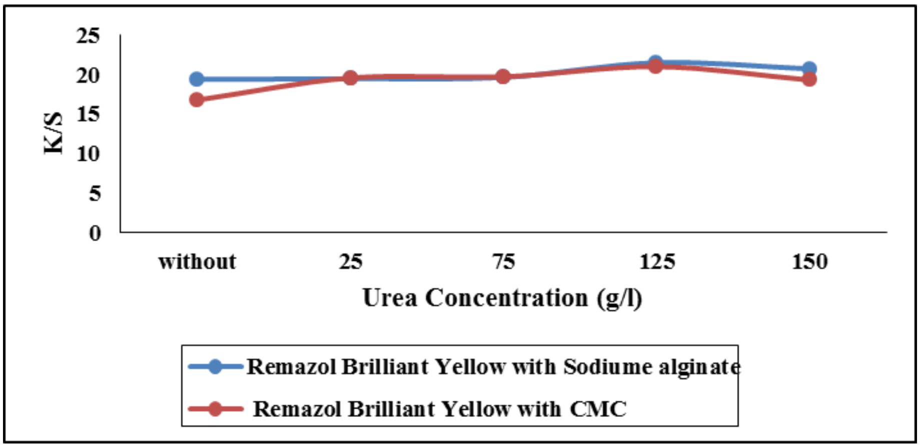

Fig (2) Effect of Urea concentration of Sodiume alginate and CMC printing paste on K/S of Remazol Brilliant yellow

It is clear from the previous table and figure that the increase in color strength of the prints when using Remazol brilliant yellow is directly proportional to the increase in urea concentrations until K/S reaches a maximum value at 125 g/Kg for both thickeners. After which K/S is inversely proportional to the increase of urea concentration.

In case of using procion blue PX-5R, the next results were obtained:

Table (3) Effect of Urea concentration of Sodiume alginate and CMC printing paste on K/S of Procion Blue PX-5R

	Urea Conc.(g/L)	Without	25	125	150	175
K/S	Procion Blue PX-5R with Sodiume alginate	17.13	17.90	19.10	13.72	11.89
	Procion Blue PX-5R with CMC	13.22	15.90	18.77	14.50	14.21

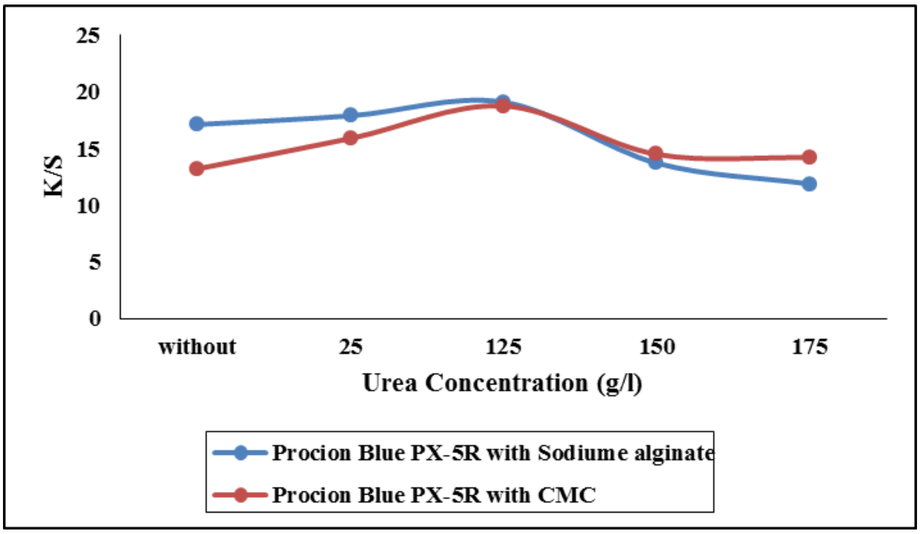

Fig (3) Effect of Urea concentration of Sodiume alginate and CMC printing paste on K/S of Procion Blue PX-5R

The previous results shows that there is a slight increase in K/S values of the prints for both thickeners until it reaches the maximum value at 125 g/L. After this value, there is a sharp decrease in K/S values at 150 and 175 g/L. The increase in color strength at 125 g/L for both thickeners can be explained on the fact that: at this concentration, urea can provide the humidity required for fixing during steaming process. As a result, urea increase water content in it is medium, which comprises both printing film and cotton fabric. Increasing water content in the printing film will increase dye solubility and its ability to transfer into cotton fabrics. It will decrease the aggregation of the dye molecules. On the other hand, increasing water content in cotton fabric will cause the swelling of the fabrics, which will accelerate the dye molecules diffusion. [11]

3-2-2 Effect of Sodium carbonate concentration

To investigate the suitable concentration of Sodiume carbonate needed to attain maximum fixation of reactive dyes on cotton fabrics, different concentrations of Sodiume carbonate were included in the printing paste. Cotton samples were printed using printing pastes of (4%) Sodiume Alginate for both reactive dyes, (4%) and (6%) CMC for Remazol Brilliant Yellow and Procion Blue PX-5R respectively with different concentrations of Sodiume carbonate. K/S of printed samples was measured and illustrated in table (4) and Fig (4).

Table (4) Effect of Sodiume carbonate concentration of Sodiume alginate and CMC printing paste on K/S for both reactive dyes

	Sodiume Carbonate Conc.(g/L)		Without	10	20	30	40
K/S	Remazol Brilliant Yellow	Sodiume alginate	4.93	21.84	21.43	21.30	20.00
		CMC	4.33	19.58	18.93	18.50	18.30
	Procion Blue PX-5R	Sodiume alginate	1.79	11.39	13.72	17.58	15.10
		CMC	0.998	12.36	14.54	15.04	14.35

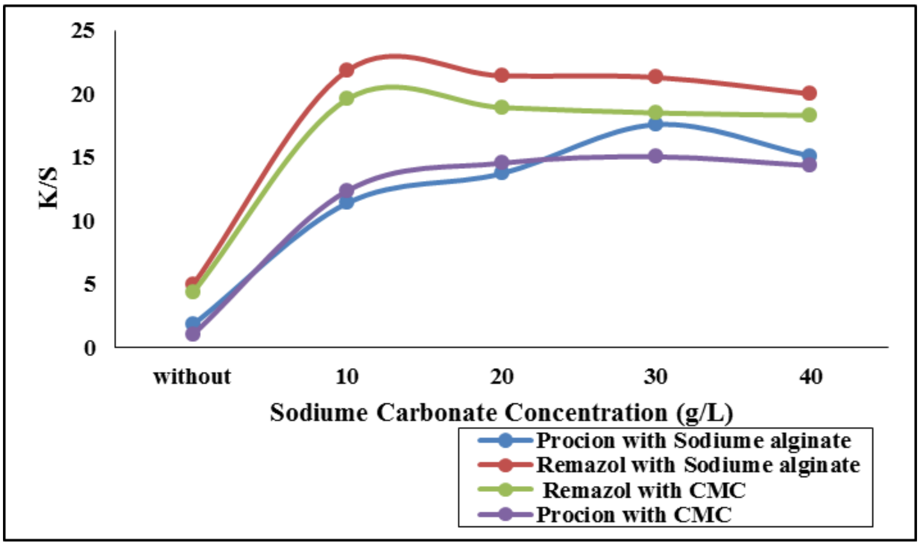

Fig (4) Effect of Sodiume carbonate concentration of Sodiume alginate and CMC printing paste on K/S for both reactive dyes

The previous results shows that there is a clear increase in K/S values of the prints until it reaches a maximum value at 10 g/Kg and 30 g/Kg for Remazol Brilliant yellow and Procion blue PX-5R respectively with both of the two thickeners. After these values, there is a slight decrease in K/S values at 40 g/Kg. The increase of K/S values at 10 g/Kg and 30 g/Kg Sodiume carbonate for both thickeners can be explained on the fact that at these concentration Sodiume carbonate could produce ionization of accessible cellulose hydroxyl groups, which can then react with reactive dyes. By Increasing Sodiume carbonate concentration gradually after these values, both the rate and the degree of dye hydrolysis will increase. [11]

3-4 Effect of Steaming temperature

Cotton samples printed with the two types of dyes and thickeners were subjected to steaming at different degrees of temperatures for fixed duration i.e. 10 min. The obtained results of K/S are showed in table (5) and Fig (5).

Table (5) Effect of Steaming temperature of Sodiume alginate and CMC printing paste on K/S for both reactive dyes

	Steaming Temperature		95°c	100°c	105° c	110°c	115°c
K/S	Remazol Brilliant Yellow	Sodiume alginate	20.37	19.84	19.67	19.25	19.01
		CMC	19.67	20.56	20.28	20.19	20.10
	Procion Blue PX-5R	Sodiume alginate	16.74	16.93	18.28	18.98	18.43
		CMC	17.01	17.29	18.13	18.74	18.24

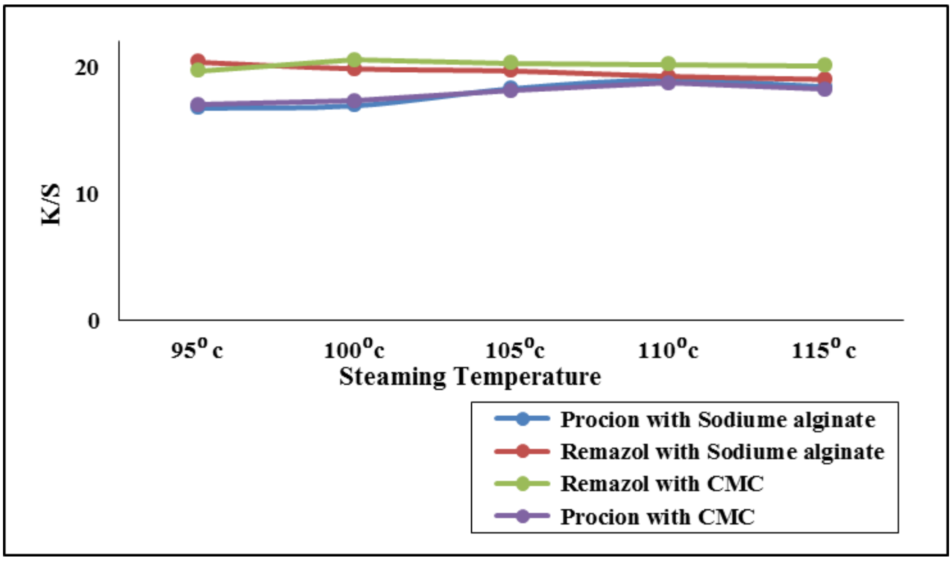

Fig (5) Effect of Steaming temperature of Sodiume alginate and CMC printing paste on K/S for both reactive dyes

The previous results leads to the indication that, maximum dye fixation and higher color strength was achieved at a temperature of 95^{0}c and 100°c for Remazol Brilliant yellow with Sodiume alginate and CMC respectively while it was 110^{0}c for Procion blue PX-5R with the two types of thickeners.

3-5 Effect of Steaming Time

To determine the suitable steaming duration within which complete reaction and maximum dye fixation may be attained, printed cotton samples were subjected to steaming at the optimum temperatures for different durations. Printed cotton samples with Remazol Brilliant Yellow were steamed at 95^{0}c and 100^{0}c for Sodiume alginate and CMC respectively while samples printed with Procion Blue PX-5R were steamed at 110°c for the two thickeners for different periods of minutes. K/S of printed samples was measured and illustrated in table (6) and Fig (6).

Table (6) Effect of Steaming time of Sodiume alginate and CMC printing paste on K/S for both reactive dyes

	Steaming Time		5 min	10 min	15 min	20 min	25 min
K/S	Remazol Brilliant Yellow	Sodiume alginate	20.11	20.95	20.91	21.23	21.01
		CMC	18.97	19.63	19.67	20.33	19.75
	Procion Blue PX-5R	Sodiume alginate	16.59	16.05	15.85	15.74	15.11
		CMC	16.78	15.71	15.57	15.20	15.13

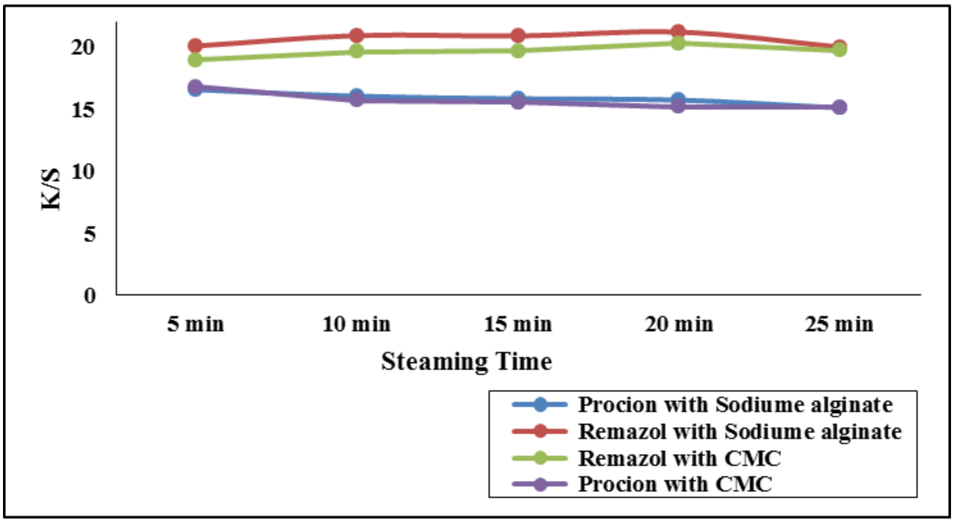

Fig (6) Effect of Steaming time of Sodiume alginate and CMC printing paste on K/S for both reactive dyes

The previous results show that, by increasing the duration of steaming, the dye fixation gradually increases until it reaches its maximum value after 20 min for Remazol Brilliant yellow with the two types of thickeners. For Procion blue PX-5R, K/S value reaches its maximum after 5 min, after that period there is a clear decrease in K/S values.

3-6 Rheological Measurements

Different concentrations of Sodiume alginate and CMC thickeners were prepared (2%, 4%, 6% and 8%) by soaking in water over night in room temperature. The two thickeners had the same weight which was 250 gm. The rheological properties of all concentrations of the two thickeners were measured. Table (7) and fig (7) show only the results of measuring 4% Sodiume alginate while results of measuring 4% CMC can be illustrated at table (8) and fig (8)

Table (7) Effect of applied force on the apparent viscosity of (4%) Sodiume Alginate Thickener

RPM	Up		Down	
	%	CP	%	CP
1	41	35720	41	35720
3	22	28720	22	28720
10	41.2	16540	41.2	16540
20	60.1	11450	60.1	11450
60	71.1	5510	71.1	5510
100	82.1	4130	82.1	4130
200	91.1	4060	91.1	4060

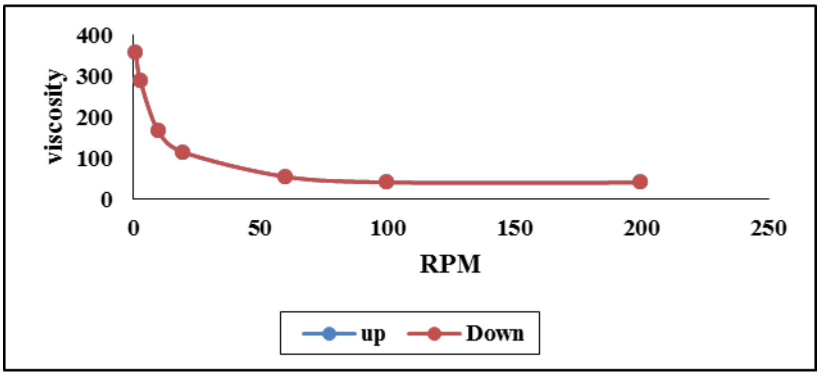

Fig (7) Rheological properties of (4%) Sodiume Alginate Thickener

Table (8) Effect of applied force on the apparent viscosity of (4%) CMC Thickener

RPM	Up		Down	
	%	CP	%	CP
1	4.7	190700	5.2	184900
3	9.4	120700	9.1	134100
10	15.5	60800	14.7	71100
20	20	39600	19.6	45600
60	31.5	19100	31.5	29800
100	33.2	13200	33	21600
200	40.5	8100	40.5	8100

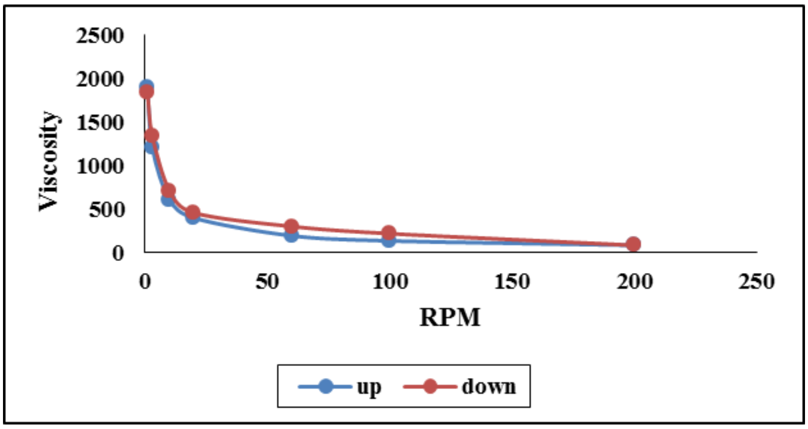

Fig (8) Rheological properties of (4%) CMC Thickener

It is clear from the rheograms shown in fig (7) that irrespective of the nature of the Sodiume alginate; the examined paste are characterized by non-Newtonian pseudoplastic behaviour. The up and down flow curves are not coincident, which indicate that if this paste subjected to a force, it is viscosity decreases as the applied forces increases from the minimum to the maximum. On the removal of the applied force, the paste retains its original viscosity immediately, i.e. it does not need a time to rebuild its structure and retain their original viscosity soon. This property, i.e. pseudoplasticity has an important role in the field of textile printing to obtain levelness and sharp outlines. [12]

The rheograms represented in fig (8) show that irrespective of the nature of the thickening agent used; the examined CMC paste is characterized by non-Newtonian thixotropic behaviour. The up and down flow curves show that this paste undergoes decrease in viscosity with time under constant strain rate. On the removal of the applied force, the paste need much time to retain its original viscosity and rebuild its structure. Depending upon the system, the time necessary for structure build up may range from a few seconds to several days. [13]

3.7 Color Fastness Properties

The fastness properties of the printed samples were tested and their results are illustrated in table (9) for Sodiume alginate and CMC.

Table (9) Color fastness of samples printed with Sodiume alginate and CMC printing paste

Dye	Thickener	Wash at 95^{o}c			Rubbing		Perspiration Acidic			Perspiration Alkaline			Light For 50 H
		Staining Co	Staining W	Alt	Wet	Dry	Staining Co	Staining W	Alt	Staining Co	Staining W	Alt	
Remazol Brilliant Yellow	Sodiume alginate	5	3-4	4-5	4	5	4	4-5	4-5	4	4	4-5	5
	CMC	5	3-4	4-5	3-4	5	3-4	4	4	3-4	4-5	4	5
Procion Blue PX-5R	Sodiume alginate	5	3-4	4	3-4	5	3	4-5	3-4	3	4	3-4	5
	CMC	5	3-4	4	3	5	3	3	3-4	2-3	2-3	4	5

The previous table show that the two types of thickeners nearly had the same results.

Washing fastness assessment of obtained colors have shown very good levels for both reactive dyes. The results obtained also showed that printed cotton samples have excellent light fastness for both reactive dyes.

The rubbing fastness results are good and acceptable showing little fading in wet rubbing shades while dry rubbing fastness results are excellent. For perspiration fastness the results are acceptable for Procion Blue PX-5R and very good for Remazol Brilliant yellow.

3.8 Some Creative designs printed with Sodiume alginate printing paste

Design no (1)
Number of colors (2)

Design no (2)
Number colors (2)

Design no (3)
Number of colors (2)

Design no (4)
Number of colors (3)

Design no (5)
Number colors (2)

Design no (6)
Number of colors (4)

4. Conclusion

It can be concluded from the previous study that Sodiume alginate thickener is the best one to be applied in the cotton printing process with an optimum concentration 4% for both reactive dyes. The Results of the rheological measurements of both thickeners indicate that Sodiume alginate is characterized by non-Newtonian pseudoplastic behaviour which provide the required viscosity to obtain sharp outlines while CMC has a thixotropic one and as a result can be applied to large areas to have levelling prints.

5. References

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