



Application of Modified Xanthan as Thickener in the Printing of Natural and Synthetic Fabrics

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Abstract

Xanthan Gum, a member of the natural thickener family, has grown in usefulness in food and industrial applications. However, when used as a thickener, Xanthan Gum showed more elastic behavior and weak gel characteristics due to its stiffness and ordered conformation, as well as printing defects like poor screen ability, low color yield, and uneven color. If modification techniques are used to alter the rheological characteristics of XG solutions to get effective printing results This work involved the deacetylation of several modified xanthan gums (MXG) using an alkali treatment at a certain temperature on cotton and silk fabrics and using it as a pretreatment of polyester fabrics. The screen ability, color yield, and penetration of printing were all enhanced when MXG was used as a thickener instead of xanthan gum. Excellent printing performances were achieved by These thickeners, which have might be good pastes to meet the requirements of cotton, silk, and polyester printing

Keywords Xanthan Gum, Modified Xanthan Gum, Printing Textile s

Introduction

Gums are compounds that, technically speaking, because of their enormous molecular weight, high water solubility, and high solubility can create gels or extremely viscous solutions at low concentrations. Although a wide range of different substances can be classified as gums and display "gummy" characteristics, in the industry this term is most frequently used to refer to plant and microbial polysaccharides and their derivatives[1]. In the 1950s, exopolysaccharides, or polysaccharides of microbial origin, were discovered for the first time[2]. However, interest in polysaccharides for food and non-food uses has rapidly increased over the last couple of decades, largely due to their enormous biotechnological value[3]. They have a variety of structural and functional characteristics due to their chemical composition, multiple

molecular linkages and groupings, and different functional features[4].

Exopolysaccharide known as xanthan gum is mostly produced by the *Xanthomonas campestris* NRRL B-1459 strain of a plant pathogenic bacterium[5, 6]. Single straight rods of *Xanthomonas* spp. are common. The cells have a single polar flagellum, are motile, and are Gram-negative[6]. Since the microbe is aerobic, oxygen is a necessary nutrient for both microbial development and the formation of xanthan[7] Due to its manufacture being relatively expensive, glucose and/or saccharose are employed as the only carbon sources, However, to lower production costs and promote waste recycling, it may be possible to extract the carbon source from wasted agricultural residues. In response to the enormous industrial demand for xanthan gum, which is primarily used by the following industries worldwide: cosmetics, pharmaceuticals, textiles, petroleum, and especially the food industry, several studies on its manufacture and characterization have been conducted. . The

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Food and Drug Administration (FDA) allowed its use in foods in 1969 due to its remarkable rheological qualities, which enable the creation of viscous solutions at low concentrations and stability over a broad pH and temperature range[2]. Production of xanthan gum is influenced by several variables, including the carbon source, microorganisms, and operational conditions. The composition of the fermentation medium, the operating system (batch or continuous) of the bioreactor, and the controlled production conditions of temperature, pH, agitation speed, aeration, and fermentation duration must all be carefully studied to get the optimal configuration. All of them lead to a high-quality gum with a good yield in terms of structure and rheological qualities. However, when used as a thickener, XG displayed more elastic behavior and weak gel features, such as poor screen ability, low color yield, and uneven color, even though it has become increasingly useful in a variety of applications[8]. Therefore, it is important to think about whether modification techniques to XG solutions alter their rheological characteristics to provide good printing results. When heated between 40 and 80 C, the XG structure undergoes a conformational change from an organized double helix to a random coil [9, 10]. To create different modified xanthan gums (MXG), deacetylation under alkali treatment at a specific temperature was used. The findings demonstrated that as the degree of modification was raised, MXG's flowability and viscous effect increased. These thickeners, which have greater flowability, more viscous behavior, and lower structural viscosity than xanthan gum, may make suitable pastes to meet the demands of reactive dye cotton printing. With good rheological characteristics like a high degree of pseudo-plasticity, a high viscosity even at low concentrations, stability and compatibility with most metallic salts, excellent solubility and stability in acidic and alkaline solutions, and good performance to overall color fastness properties to wash, xanthan gum produced by the bacterium *Xanthomonas campestris* and by other species of *Xanthomonas* were used as a printing thickener on cotton fabrics[11]. By chemically modifying xanthan gum with alkali and monochlorotriazine di-sulfanilic acid (TS) as modifiers, a novel thickener known as (TDG) s-triazine di-sulfanilic xanthan was created. TDG significantly outperformed XG in terms of screen ability, color yield, penetration, and outline sharpness when employed as a thickener in reactive printing on silk cloth. To enhance the clarity and color depth of inkjet printed patterns, the polyester fabric was pretreated with xanthan gum, a bio-based thickening agent, along with numerous metal salts (NaCl, KCl, CaCl₂, and MgCl₂).

Xanthan gum

An extracellular polysaccharide called xanthan gum is produced when the fermentation of bacteria *Xanthomonas* sp. It is a biopolymer made up of 3:3:2 units of D-glucose, D-mannose, and D-glucuronic acid. Acetyl and pyruvic acid groups are also present. In either cold or hot water, xanthan gum quickly dissolves, resulting in an extremely viscous solution if the concentration is low. pH and temperature have virtually little impact on the solution's viscosity.

These qualities make xanthan gum an ideal thickening ingredient for usage in foods, textiles, and pharmaceutical products. It is utilized as an emulsifier in a wide range of industrial processes, and secondary oil recovery procedures benefit particularly from its efficiency. *Xanthomonas campestris* PV manihots was used to make the xanthan gum, which produced high-quality gums in terms of viscosity, pH, and temperature stability. The fermentation took place in a medium comprising sucrose, dipotassium phosphate, and magnesium sulfate for 96 hours at 250 rpm. the temperature was set to 30°C and pH 7. [12]

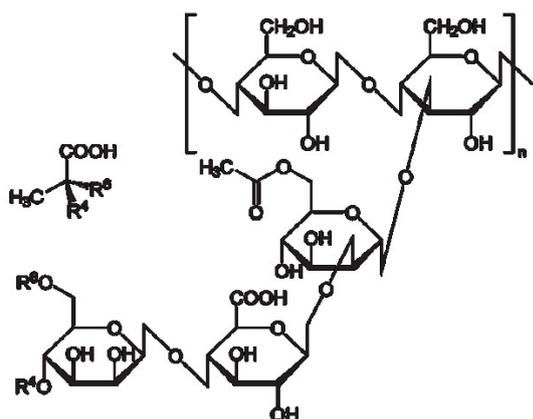
Two fundamental groups were created by variant gums; one set has subunits with different amounts of acetylation and pyruvate on sidechain residues. These forms are known as acetylated and nonacetylated tetrameric repeat forms and are abbreviated as utet and natet. [13]

The most significant properties of XG include [14]

- Low amounts of it have a high viscosity.
- suitability for the majority of metallic salts.
- high elasticity due to the ordered structure.
- stability for a wide range of temperatures, acids, alkalis, and pH.
- It provides good stability to sunshine, washing, light, and friction.

Chemical structure of xanthan:

The primary structural component of XG, which is produced by the bacterium *Xanthomonas campestris*, is repeating pentasaccharide units made up of two glucose units, two mannose units, and one glucuronic acid unit [15]. A charged trisaccharide side chain is substituted at C-3 every other unit in the main chain, which is made up of (1-4)-b-D-glucan cellulose. A b-D-glucuronic acid residue is present in the trisaccharide side chain in between two D-mannose units. There is an acetyl group at position C-6 of the inner a-D-mannopyranoside connected to the main chain. A pyruvic acid residue connected to the 4 and 6 positions of one-half of the terminal b-D-mannopyranoside by a keto group [16].



Fig(1) Chemical structure of xanthan gum

Xanthan gum production:

There is numerous research from various authors available about the circumstances surrounding the synthesis of xanthan gum [17-19], and the microorganism utilized to generate the gum[2, 20, 21], claiming that variances affect the results greatly in terms of yield and quality. The formation of xanthan gum is aided by the presence of organic acids and occurs through aerobic fermentation at a temperature of between 27 and 30°C. The bacterium can convert roughly 70% of the substrate to gum in the industrial procedure. to produce a product of high quality while maintaining optimum efficiency. The production of xanthan gum was made in **two** steps:

1. **Cell generation:** 1% glucose, 0.3% yeast extract, 0.3% malt extract, and 0.5% peptone were all present in the YM medium. Before sterilization, the pH was corrected with sodium hydroxide to 7.0. The cells were grown in 1000 mL Erlenmeyer flasks with 220 mL YM media for 24 hours at 25°C and 250 rpm using a New Brunswick rotary shaker. [12]
2. **the creation of xanthan gum:** At 30°C and 250 rpm for 48 hours, seed cultures (220 mL) was inoculated in 450 mL of the medium containing 2% sucrose, 0.5% K₂HPO₄, and 0.01% MgSO₄ (PH = 7.0). The fermentation broth was centrifuged after being diluted with 3 vol. of sterile distilled water (7,000 xg for 30 min) To precipitate the polysaccharide, 3 vol. of 99.5% ethanol was added to the supernatant. This precipitate was resuspended, dialyzed for 72 hours against running tap water, and then heated to 55 °C to dry it to constant weight.[12]

Microorganism Xanthomonas

- is a genus of small, rod-shaped, aerobic, Gram-negative bacteria of the Pseudomonadaceae family.
- The majority of the xanthan gum-producing species in this genus are plant pathogens.[22, 23]
- Different yield and gum properties can be produced by altering the strain as well as the processing parameters.
- Several studies focused on using several Xanthomonas species to produce xanthan gum. [2]
- The results showed that *X. campestris* pv. *Campestris* produced 9.67 g.l-1 of xanthan gum.
- *X. arboricola* pv. *pruni* strain 106 was employed in a different investigation, and the best outcome obtained was 19.5 g.l-1. [24]
- Xanthan gum was created, and the pH and airflow throughout the process had a significant impact on the final product. The production technique using the *X. arboricola* pv. *pruni* strain generated a good yield of 26.4 g.l-1, but the gum produced had the lowest viscosity.[25]

The *X. campestris* strain needs micronutrients like potassium, phosphate, and calcium salts as well as macronutrients like carbon and nitrogen. Glucose and saccharose are the two most typical carbon sources. The use of agro-industrial wastes as a carbon source has, however, been researched in recent decades. While nitrogen, phosphorus, and sulfur had a direct impact on the formation of xanthan gum, nitrogen, phosphorus, and magnesium had a direct impact on bacterial growth. [26]

Carbon sources

Waste agricultural products are produced by industrial operations. These products may lead to the development of novel processed goods with commercial potential, including alcohols, enzymes, organic acids, and amino acids[27]. Residues such cassava bagasse [17, 28], green coconut shells [29], apple juice residue [30], sugarcane[31-33], glycerin, and vegetable leftovers have all been put to use through various procedures.[34]

COMPATIBILITY

With a wide variety of chemicals and additions, both food- and non-food-related, xanthan gum creates solutions. As we will see later, in some circumstances, the degree or level of compatibility depends on the concentration of xanthan gum utilized.

Salt

At salt (sodium chloride) levels larger than around 0.1%, the presence of ionic material stabilizes the xanthan gum, giving additional stable viscosity. Since salt is commonly used in foods at levels greater than 0.1% for flavor and preservation. It should be emphasized that viscosity stability can only be produced at low salt concentrations.

Many food products, including soy sauce, marinades for meat, and "half-fabrics" or incomplete food preparations, will have long-term viscosity stability thanks to the sodium chloride content of xanthan gum, which ranges from around 0.1% to over 20%. [35]

Temperature

According to some research, a fermentation temperature of 28 °C produced the highest gum output. Additionally, xanthan gum manufactured at high temperatures (around 34 °C) has low acetate and pyruvate levels and low average molecular weight, resulting in poor viscosity in its aqueous solutions. Xanthan gum with a high acetate concentration and a high average molecular weight was created at a low temperature of 25 °C, yielding solutions with a high viscosity.

Cell lysis was seen when the broth wasn't handled under the proper conditions (80–130 °C, 10–20 min, pH 6.3-6.9), which prevented the xanthan gum from dissolving thermally. The viscosity of the medium likewise decreased as the temperature rose. [35]

pH

For growth, pH values between 6.0 and 7.0 and temperatures between 25 and 27 °C produced the best results. For the generation of xanthan gum and its viscosity, pH values around 8.0 and temperatures of 30 °C produced the best results. According to a study, pH regulation boosted microorganism growth but had little impact on xanthan gum output. In conclusion, the majority of writers concurred that controlling pH in the range of 6.0 to 8.0 with the use of alkalies like KOH, NaOH, or (NH)₄OH was beneficial for the manufacture of xanthan gum. [35]

Alcohol

Xanthan gum can be used to make food alcohols more viscous by up to 60% by weight. The gum becomes incompatible with the alcohol above this point, and a gel is produced. Alcohol concentrations below 60% result in thicker solutions, whose viscosity depends on the quantity of gum used. This thickening ability is used in commercial alcohol preparations, chocolate confectionery fillings, dry mixes, and ready-to-drink alcoholic beverages. [35]

Enzymes

Enzymes frequently found in food products and raw materials do not depolymerize xanthan gum solutions. Because of its ability to prevent solid separation and provide viscosity, this gum is widely used to stabilize foods that are known to have lingering enzyme activity, such as pineapple preparations and a variety of hot sauces. [35]

APPLICATIONS OF XANTHAN GUM

- 1) Xanthan gum has been investigated as an elicitor in agriculture to inhibit the *Bipolaris sorokiniana*, which damages barley cultivars, along with fungicides. [36]
- 2) In the food business, xanthan gum is used as an emulsifier and thickening agent in a wide range of products, including juice, fruit pulp and powder beverages, chocolates, sweets, jellies, dairy products, margarine, yogurt, bread goods, frozen meals, sauces, and gravies.
- 3) To lower the cost of manufacture, guar gum and locust bean gum are combined with xanthan gum. [37]
- 4) As needed by modern food items, Xanthan gum offers texture, viscosity, flavor release, appearance, and water-control qualities.
- 5) Because of its higher Newtonian features and pseudoplastic activity in solutions, xanthan gum also enhances the rheology of the finished products. [17]
- 6) When drilling in the oil industry, a 0.5% xanthan glue solution can maintain the water-based drilling fluid's viscosity and control its rheological properties, make tiny bit parts rotate at high speeds while maintaining high viscosity, significantly reduce power consumption, and prevent borehole wall collapse as well as making cutting debris discharge effects easier.
- 7) It is superior to gelatin, CMC, seaweed gum, pectin, and other common food additives in the food industry, adding 0.2% to 1% to juice to improve adhesion, flavor, control penetration, and flow; When used as a bread addition, it can provide bread a stable, smooth texture, save time, and lower the cost. Utilizing 0.25% in bread filling, food filling, and frosting can improve taste and flavor, facilitate product organization, extend shelf life, and enhance the stability of products when heated and frozen; Ice cream with 0.1% to 0.225% added can have a good stabilizing impact in dairy products; gives canned goods good viscosity control.
- 8) It can replace some starch; 3 to 5 parts of starch can be replaced by 1 part of xanthan gum. Xanthan gum has also been widely

employed in liquid food, frozen food, desserts, and flavorings.

- 9) Biochemical investigation. Emulsifiers and stabilizers for use in cosmetics, non-food products, and food.

Modified Xanthan gum in printing textile

The rheological properties of XG solutions are changed by modification methods to achieve good printing effects needs on different fabrics.

Using MXG for printing cotton with reactive dyes in screen printing

Different modified xanthan gums (MXG) were created by deacetylating various xanthan gums with an alkali solution at a specific temperature (90 C). After alkali treatment, xanthan gum's molecular weight dropped. Flowability, thixotropy, and viscoelasticity rheological parameters were examined using steady-shear, transient, and dynamic oscillatory testing. The findings demonstrated that as the degree of modification rose, the structural viscosity and elastic effect reduced while the flowability and viscous effect of MXG increased. The screen ability, color yield, and penetration of printing were all increased when MXG was used as a thickener instead of xanthan gum.

Chemical modification of Xanthan Gum

-Biopolymer hydrolysis in an alkaline environment at a specific temperature was the modification technique.

-In a vacuum oven, XG powder was dried to a set weight.

-The quantitatively standard NaOH solution about repeated pentasaccharide units was gradually added to the XG solution in 1,000 ml three-necked flasks containing 0.933 wt% XG solution throughout incubation at 90 C and 600 rpm.

- The modified sample was precipitated repeatedly using acetone after a 4-hour reaction, dried, and ground into powder.

-The repeating pentasaccharide unit (C₃₅H₄₉O₂₉) states that a solution containing 0.933 weight percent of XG is equivalent to a solution containing 0.01 mol/L of the unit.

In the modified procedure, the molar ratios of alkali to repeating pentasaccharide units were 0:1, 0.172:1, 0.344:1, 0.516:1, 0.687:1, 0.802:1, 0.917:1, and 1.21:1, respectively. These ratios translate to MXG as 0, 0.172, 0.344, 0.516, 0.687, 0.802, 0.917, and 1.21

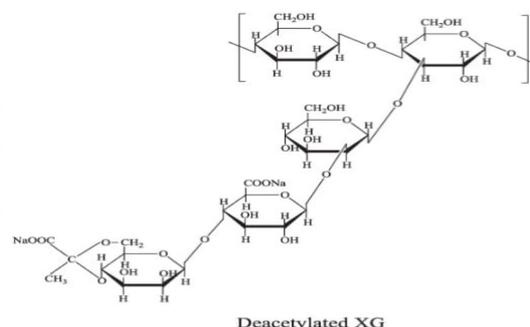
Preparation of the printing paste and the screen printing process

- To achieve full swelling, the thickener and demineralized water were thoroughly mixed in a mixer and placed in the refrigerator overnight.

- Printing pastes were prepared

table 1 (a)The amount of thickener solid content in the original paste solution is 3 wt%

MXG.



(Fig.2) Chemical modification of XG by deacetylation to MXG

Table 1 Printing paste recipes

Ingredients	Amount (g)
Original paste	700 ^a
Reactive dye	10
Urea	50
Reservehao S	10
Sodium bicarbonate	10
Water	220
Total	1,000 ^b

- after which they were rinsed in cold and warm water, respectively, and then immersed in boiling water for 10 minutes at a bath ratio of 1:50 to remove the thickener and unfixed colors.

Figure(3) shows that the intrinsic viscosity of MXG is lower than that of XG; moreover, it has a decreasing trend as the number of alkalis increases.

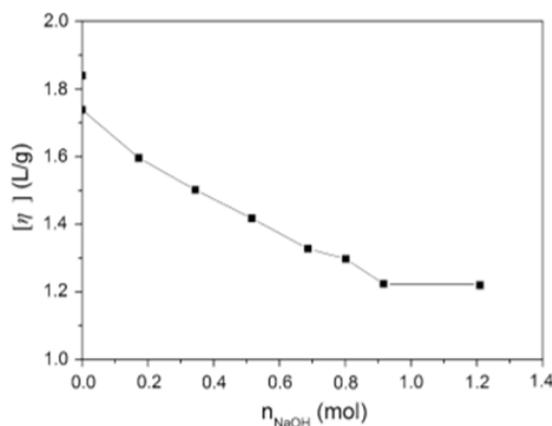


Fig. (3) Intrinsic viscosity of XG by different amounts of alkali modification relative to repeated pentasaccharide units of 1 mol.

(Table 2) makes it abundantly evident how the alkali alteration of XG reduced its molecular weight to various degrees. Similar to how different MXGs' intrinsic viscosities alter, molecular weight tends to decline as alkali content rises. Additionally, the FT-IR spectra demonstrated that the alkali alteration eliminated the acetyl group. The side chains of XG become more flexible following deacetylation, and the acetate residues contribute to the intramolecular interaction [38]. As a result, after alkali alteration, the molecular chains of XG may also become more rheologically flexible, resulting in a reduction in chain dimension. Table(3) indicates the viscosity with different degrees of modification :

(Table 2) Molecular weights of different MXGs

Sample	M_w	M_n	M_w/M_n
0 MXG	2,466,343	1,098,809	2.2446
0.687 MXG	1,242,083	502,748	2.4706
0.802 MXG	1,155,156	461,972	2.5005
0.917 MXG	501,978	185,293	2.7091

(Table 3) VISCOSITY OF 3 wt% XG solutions with different degrees of modification at 25

Xanthan solutions	n
XG	0.134
0 MXG	0.0269
0.172 MXG	0.287
0.344 MXG	0.301
0.516 MXG	0.334
0.687 MXG	0.369
0.802 MXG	0.385
0.917 MXG	0.451
1.21 MXG	0.445

Printing performances of XG with different degrees of modification

- Using the criteria of paste add-on, color yield, penetration, and color unevenness, the printing characteristics of a large pattern for XG with various levels of modification were described. Investigated were the impacts of the degree of alteration on the printing capabilities. The connections between printing capabilities and rheological characteristics have first been studied.

- In screen printing, the screen ability of the printing pastes is crucial since it directly affects other printing results. The paste addition, color yield, and penetration were all increased to varied degrees when employing MXG as a thickener compared to XG, increasing by 30–50%, 32–57%, and 5–66%, respectively

- Besides, with the increase in the degree of modification, the printing performances get better and better. Rheological measurements demonstrated that the rheological properties of

MXG had been changed owing to the reduction of molecular weight and weaker intra-molecular forces after alkali modification. As shown by the rheological and printing data in Table 4, the larger the modification degree is the larger n(VISCOSITY) and d, the better the color yield, penetration, and color evenness. Elasticity has effects on the flow behavior of the paste through the screen openings to the fabric and the fibers by rapidly controlling the recovery of the paste after its application. The more viscous behavior of paste contributes to passing through the screen openings onto the fabrics and penetrating the fibers.

Table(4) Printing performances using different MXGs as thickeners characterized by different rheological properties:

Printing paste	Paste add-on (g m^{-2})	Color yield (%)	Penetration (%)	Color unevenness (%)	Rheological parameters ^a			
					n	G' (Pa)	G'' (Pa)	δ ($^\circ$)
XG	52.7	3.971	37.60	10.68	0.134	32.28	8.36	14.31
0 MXG	72.0	4.605	42.40	10.47	0.269	5.95	4.02	34.07
0.172 MXG	71.5	5.232	39.58	10.37	0.287	4.90	3.82	37.93
0.344 MXG	71.4	5.643	47.73	10.82	0.301	4.01	3.45	40.77
0.516 MXG	69.1	5.752	43.40	12.91	0.334	3.35	3.30	44.51
0.687 MXG	73.2	5.971	57.27	11.17	0.369	2.97	3.12	46.34
0.802 MXG	75.5	6.238	62.40	6.95	0.385	1.67	2.30	54.06
0.917 MXG	78.3	6.104	59.48	7.81	0.451	0.75	1.51	63.61
1.21 MXG	76.2	6.200	61.25	7.53	0.445	0.37	1.09	71.21

^a n is obtained from flow curves correlated with the power-law model. G' , G'' and δ are calculated with the Friedrich-Braun model at a frequency of $\omega = 1 \text{ rad s}^{-1}$.

Using XG by *Xanthomonas campestris* for printing cotton with reactive dyes in screen printing:

When employed as a printing thickener on cotton fabrics, xanthan gum (produced by *X. campestris* utilizing tofu dregs as its carbon source) performed comparably to sodium alginate and commercial xanthan gum. According to SNI ISO 105-C06-2010, printing characteristics were assessed by measuring K/S value, fabric stiffness, and color fastness to rubbing, washing, sweating, and sunshine. The findings demonstrated that when employed as a thickener on cotton fabrics with reactive dyes, xanthan gum derived from tofu dregs bio-conversion had good performance on overall color fastness capabilities. Colorfastness to dry gives a value of 4-5 and to wet rubbing of 3-4, which is higher than the values provided by commercial xanthan gum and alginate of 3 and 3-4, respectively. Colorfastness to washing (value of color stains) yields a value of 4-5, which is higher than the value of 4 provided by commercial xanthan gum and comparable to that of sodium alginate. Similar findings revealed that xanthan gum derived from tof

Similar findings revealed Xanthan gum derived from tofu dregs performs better in terms of K/S, with a value of 11.949, than its commercial version, which has a value of 4.476.

The stiffness of cotton fabrics using xanthan gum produced from tofu dregs was higher than commercial xanthan gum in the textile printing process with reactive dyes. Xanthan gum from tofu dregs has good performance for application in the textile printing process with reactive dyes.

Preparation of the printing paste and the screen printing process

Thickening agent preparation: Thickening agent was prepared by using xanthan gum tofu dregs, xanthan gum commercial and sodium alginate 5% w/v respectively. The dispersion mixture was stirred followed by adding the water until a thick emulsion was formed.

Printing paste preparation: The combination was used to create the printing paste for reactive dye printing on cotton fabrics (Table 5). A paste weighing 1 kg is created by properly combining all ingredients with just enough deionized water.

Printing procedure: The flat-hand screen printing method was used to print cotton. The dried printed samples were fixed by superheated steam at 180 C for 1 min. after being dried at 100 C for 2 min. Printing samples were thoroughly cleaned using

cold water for 15 minutes, followed by hot water for 15 minutes at 80 degrees Celsius, soaping agent for 2 ml/l, and finally room temperature air drying[39].

Table5. composition of the printing past in 1 kg

Material	Unit	Value
Thickening agent	g	700
Urea	g	20
Resist salt	g	1
Reactive dyes	g	30
Sodium carbonate	g	2
Deionized water	g	247

Color Value: A study on reactive printing using three distinct thickening agents (commercial xanthan gum, xanthan gum from tofu, and sodium alginate) was conducted. Table 6 displays the impact of various thickeners on color value. The K/S values of the samples printed using commercial xanthan gum, sodium alginate, and xanthan gum (tofu dregs) are 11.946, 3.894, and 5.844, respectively. The best-printed results were obtained with xanthan gum (tofu dregs), followed by sodium alginate and commercial xanthan gum, respectively. The depth of colour of the printed sample benefits from a higher K/S value (Fig. 4).

Table 6. color value of printed cotton fabric using different of thicking agent

Thickening Agent	Area	K/S	L*	a*	b*	ΔE	Handling	Sharpness level
Xanthan gum (tofu dregs)	Up	11.946	37.73	6.47	-40.39		Very Good	Very Good
Commercial xanthan gum	Up	3.894	47.42	6.15	-35.85	6.36 (high)	Good	Good
Sodium alginate	Up	5.844	36.60	6.59	-23.83	7.72 (high)	Good	Good

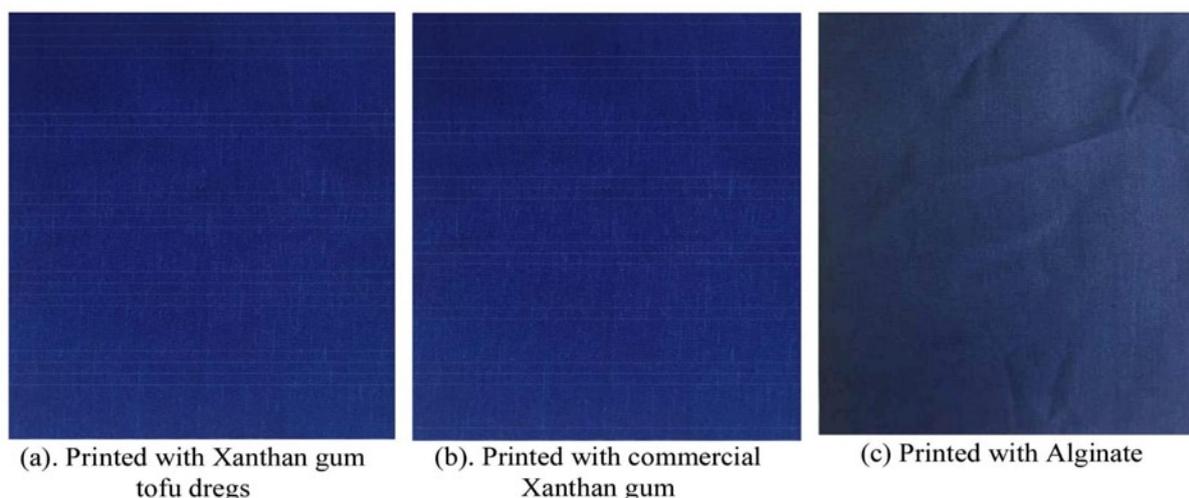


Fig.4. Cotton fabrics printed by thickeners

Table 7. Colorfastness of printed cotton fabric using a different thickening agent

Color Fastness	Thickening Agent			
	Xanthan gum (tofu dregs)	Commercial xanthan gum	Sodium alginate	
Rubbing (SNI ISO 105-X12: 2012)	Wet	3-4	3	3-4
	Dry	4-5	4-5	4-5
Washing (SNI ISO 105-C06: 2010)	Change of color	4-5	4	4-5
	Stain of color	4-5	3	4-5
Sweat (SNI ISO 105-E04 : 2010)	Change of color	4-5	4	4-5
	Acid	4-5	4	4-5
	Base	4-5	4-5	4-5
	Stain of color	3-4	4-5	4-5
Sunlight (SNI ISO 105-B01: 2010)	Base	4	4-5	4-5
	Acid	4-5	3-4	4

Where, 1= very poor; 2 = poor; 3 = Good; 4 = very good; and 5 = excellent

Table 6 and Figure 4 demonstrate the good handling qualities and sharpness level of the printed products utilizing xanthan gum (tofu dregs). According to the study's findings, xanthan gum tofu dregs had a K/S value of 11.946, 5.844, and 3.894, respectively, for color depth. When compared to sodium alginate and its commercial equivalent, xanthan gum (tofu dregs) has superior handling characteristics and sharpness levels, producing the best-printed results. In Table 7, a study of the fastness characteristics of printed cotton fabrics thickened with xanthan gum (tofu dregs), sodium alginate, and commercial xanthan gum as thickening agents is shown. The washing fastness rating of printed cotton fabrics using tofu dregs (xanthan gum) is excellent, achieving a comparable result to sodium alginate thickener (4-5).

Using TDG for printing silk with reactive dyes in screen printing

A novel thickener called s-triazine di-sulfanilic xanthan (TDG) was created by chemically altering xanthan gum (XG) using alkali and monochlorotriazine di-sulfanilic acid (TS) as modifiers to achieve good double-sided printing patterns on silk fabric. Infrared spectrophotometry using the Fourier transform was used to describe the structure of TDG. Step-shear, dynamic strain sweep and steady-shear experiments were used to study rheological phenomena. The outcomes showed that TDG outperformed XG in terms of flowability and structural viscosity. When subjected to external forces, TDG consistently displayed viscous effects, whereas XG went through the transition from elasticity to viscosity. TDG significantly outperformed XG in terms of screen ability, colour yield, penetration, and outline sharpness when used as a thickener in reactive printing on silk cloth during screen printing. TDG has even better double-sided printing capabilities than sodium alginate, suggesting that it has a lot of potential as a thickener for double-sided patterning.

Preparation of TDG :

- A three-necked flask (1000 mL) containing 0.01 mol/L XG solution was made, and it was incubated at 90°C with an orbital shaker running at 600 rpm (40). The standard NaOH solution was then gradually added to the XG solution while maintaining the molar ratio of NaOH to repeating pentasaccharide units at 0.917:1.[40]
- A quantitative addition of TS solution was made to the flask at 90 C after 4 hours. According to the literature, cyanuric chloride and sulfanilic acid were used to create the TS modifier [41]. The repeating galactomannan unit and the TS modification were mixed in a 1:1 molar ratio.
- The sodium carbonate solution, 1.2 g/L, was then added dropwise to the flask. The modified sample was precipitated three times with alcohol after 75 minutes, dried, and ground into a powder [41]. Dimethylformamide alcohol was used to purify the raw material to create TDG powder. [41]

Preparation of printing pastes and screen-printing techniques

- The thickener was dissolved in deionized water, combined, and mixed with a mixer before being refrigerated overnight to achieve full swelling [41].
- To make the printing paste, the thickening solution was combined with 10 g/kg reserve S, 50 g/kg urea, 20 g/kg dyestuff, and 10 g/kg sodium bicarbonate. This mixture was then agitated for 10 to 15 minutes [41]. Using a laboratory printing device, the exquisite designs were printed on silk cloth. All printed samples were dried for two minutes at 80 C. The squared samples were then steamed in a high-temperature steam oven for 10 minutes at 102 C. They were then immersed in boiling water with a bath ratio of 1:50 for 10 minutes at 95 C. to remove the thickener and unfixed dyes [42].

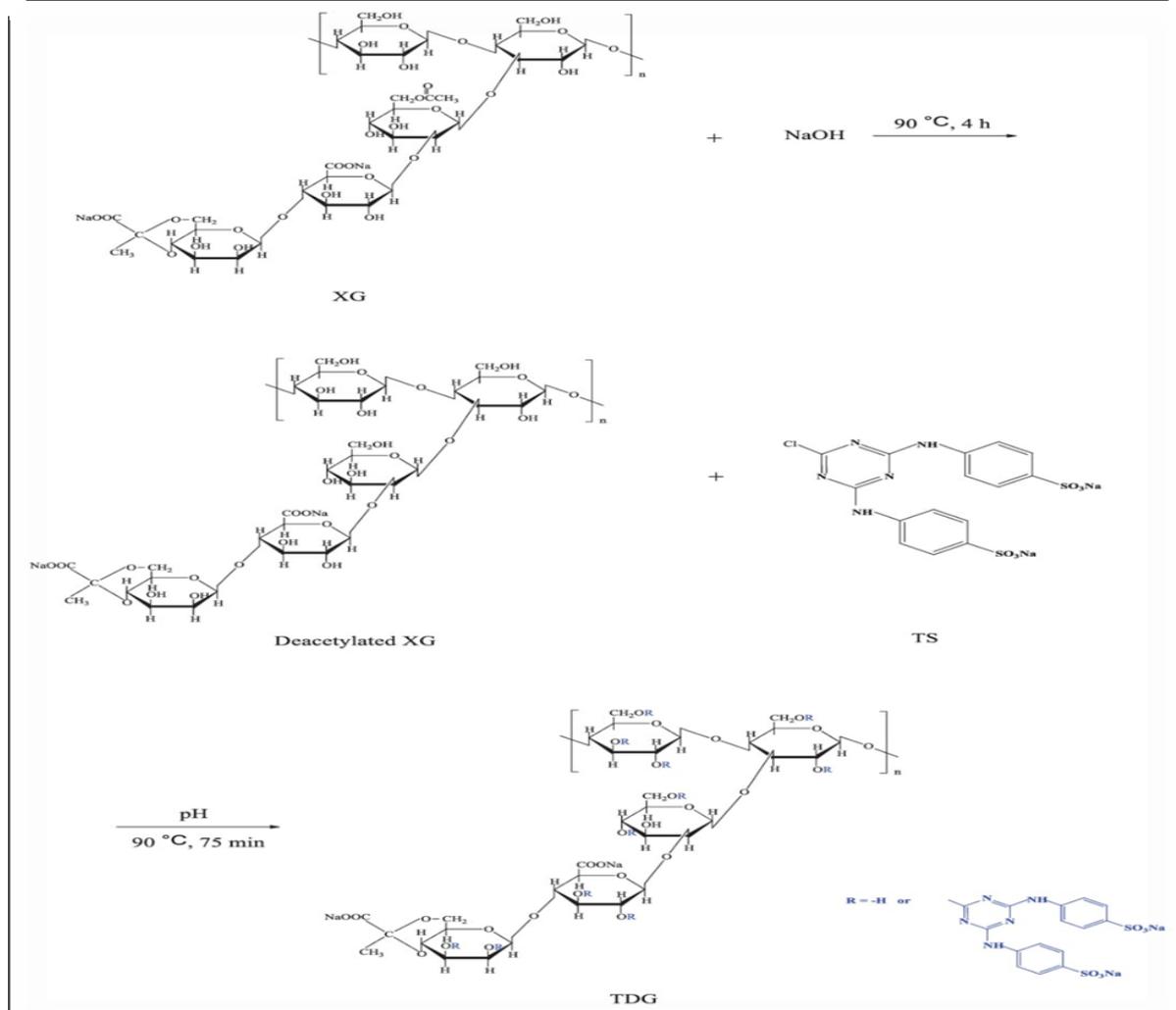


Figure 5. Chemical modification of XG by deacetylation and TS modifier.

TDG: s-triazine di-sulfanilic xanthan, TS: monochlorotriazine di-sulfanilic acid, XG: xanthan gum.

Rheological characteristics of TDG

It was inevitable that XG's rheological properties would change after chemical treatment. The printing performance, including screen ability, color yield, penetration, levelness, and outline sharpness, is influenced by the thickener's rheology. As a result, there were strong relationships between the rheological properties and the double-sided printing effects of thickening on silk fabric. ability to flow in constant shear. Figure 2 displays the TDG and XG flow characteristics.

TDG: s-triazine di-sulfanilic xanthan, XG: xanthan gum.

- TDG and XG viscosity remained high at low shear rates and significantly decreased as shear rates increased
- Figure 6 also shows that perceived viscosity rose as the thickening concentration increased
- 3 wt% TDG had a significantly lower apparent viscosity under shears than 3wt% XG, indicating that TDG had better flow characteristics.
- At the same concentration, TDG and XG had viscosity and elastic properties that were considerably dissimilar. TDG and XG exhibited stable viscoelastic and viscoelastic characteristics in the linear viscoelastic region 0–30%. With stresses, G'' of TDG always exceeded G' and d exceeded 45, demonstrating the more viscous effects of TDG. On the other hand, within the linear viscoelastic zone, G' of XG was significantly bigger than G'' and d was much less than 45, showing the stronger elasticity effects. (g' meaning the elastic components of the polymer solution) (g'' meaning the viscous components of the polymer solution)

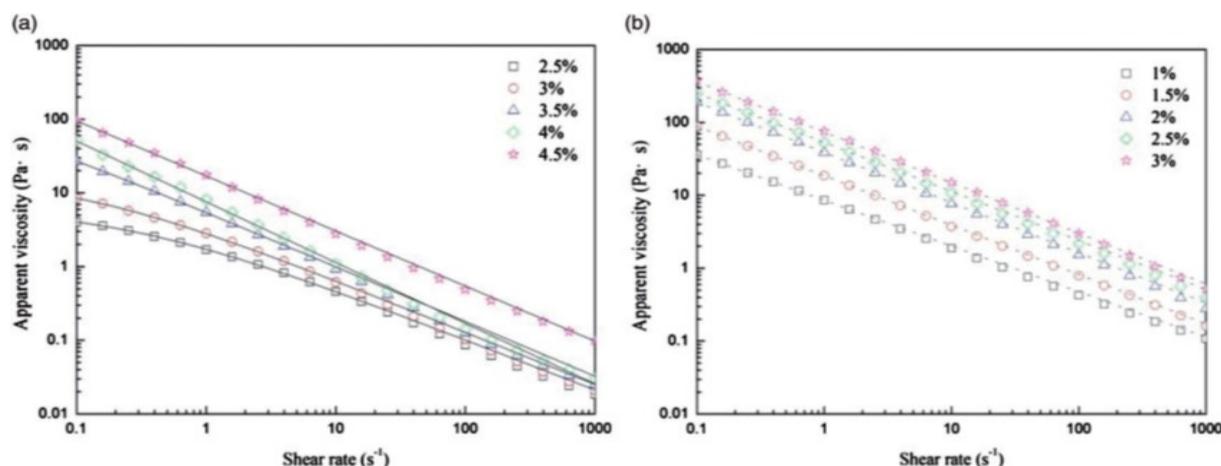


Figure 6 Flow curves of (a) TDG and (b) XG at different concentrations at 25_C; The full lines represent the fitting of data by the Cross model and the dashed lines the fitting of data by the Power-law model.

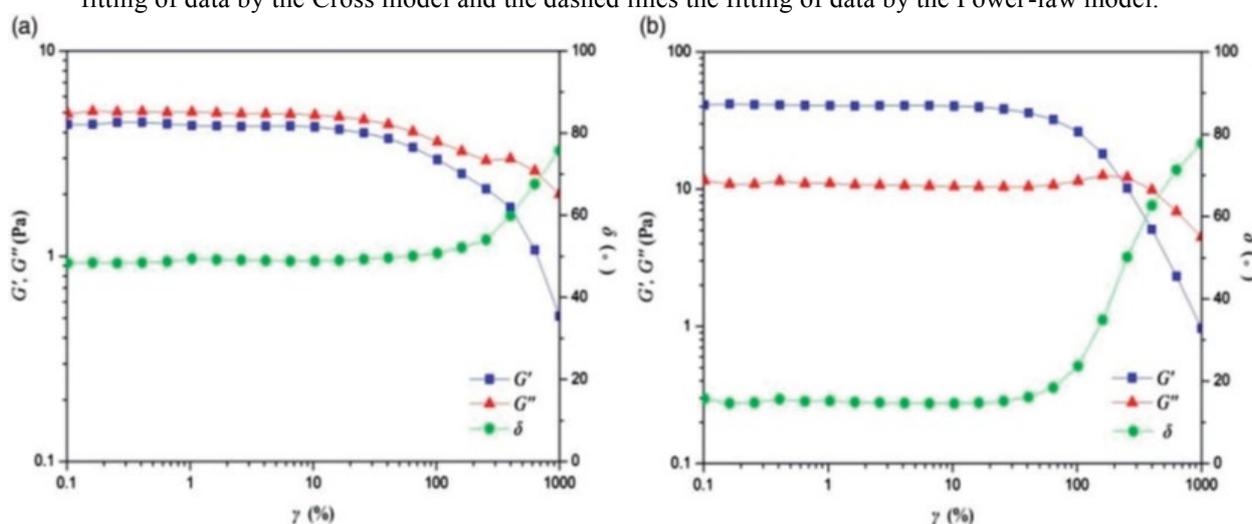


Figure 7. Viscoelastic parameters as functions of strains for (a) TDG and (b) XG at the same concentration 3wt % at 25_C.

Table 8. Large pattern qualities of the printed silk satin using TDG and XG as thickeners at different concentrations

Paste	Concentration (wt %)	Paste add-on (g/m ²)		PR (%)	CVC (%)
		K/S			
TDG	2.5	80.41	13.33	92.34	4.51
	3	82.02	13.61	91.27	4.02
	3.5	80.65	12.36	92.13	5.62
	4	80.72	12.65	89.84	6.67
	4.5	74.53	12.01	88.65	6.85
XG	1	50.25	7.42	83.68	9.98
	1.5	48.32	7.34	83.02	9.37
	2	48.68	7.64	77.52	9.18
	2.5	46.41	7.87	79.89	11.21
	3	43.21	7.05	71.23	14.89

CVC: color variation coefficient; K/S: color yield; PR: penetration rate; TDG: s-triazine di-sulfanilic xanthan; XG: xanthan gum.

Table 9. Large pattern qualities of the printed silk satin using TDG, XG, and SA as thickeners at the same concentration of 3wt % With different reactive dyes

Reactive dyes	Thickeners	Paste add-on (g/m ²)		PR (%)	CVC (%)
		K/S			
C.I. Reactive Red 245	TDG	82.02	13.61	91.27	4.02
	XG	43.21	7.05	71.23	14.89
	SA	78.65	10.54	90.86	4.35
C.I. Reactive Orange 13	TDG	78.68	7.23	93.32	5.32
	XG	40.41	2.18	81.74	12.31
	SA	68.34	5.53	91.36	3.29
C.I. Reactive Blue 49	TDG	80.32	6.42	92.73	6.58
	XG	46.19	3.47	83.04	11.19
	SA	67.92	5.01	91.19	4.82
C.I. Reactive Black 39 and Brown 11	TDG	84.63	16.63	95.13	6.26
	XG	45.37	9.66	84.17	12.86
	SA	80.07	15.04	90.80	4.69

CVC: color variation coefficient; K/S: color yield; PR: penetration rate; SA: sodium alginate; TDG: s-triazine di-sulfanilic xanthan; XG: xanthan gum.

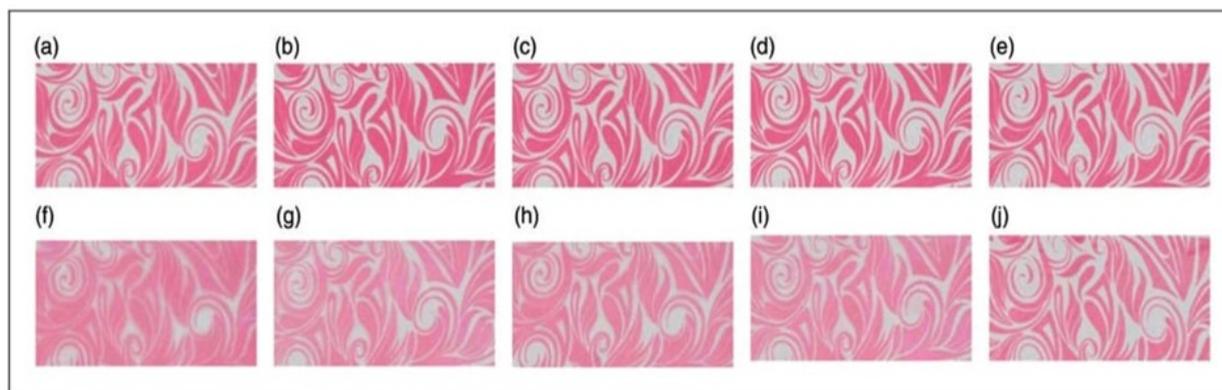


Figure 8. Fine pattern qualities of the printed silk satin using TDG and XG as thickeners at different concentrations. (a) 2.5% TDG, (b) 3% TDG, (c) 3.5% TDG, (d) 4% TDG, (e) 4.5% TDG, (f) 1% XG, (g) 1.5% XG, (h) 2% XG, (i) 2.5% XG, (j) 3% XG.

TDG: s-triazine di-sulfanilic xanthan, XG: xanthan gum.

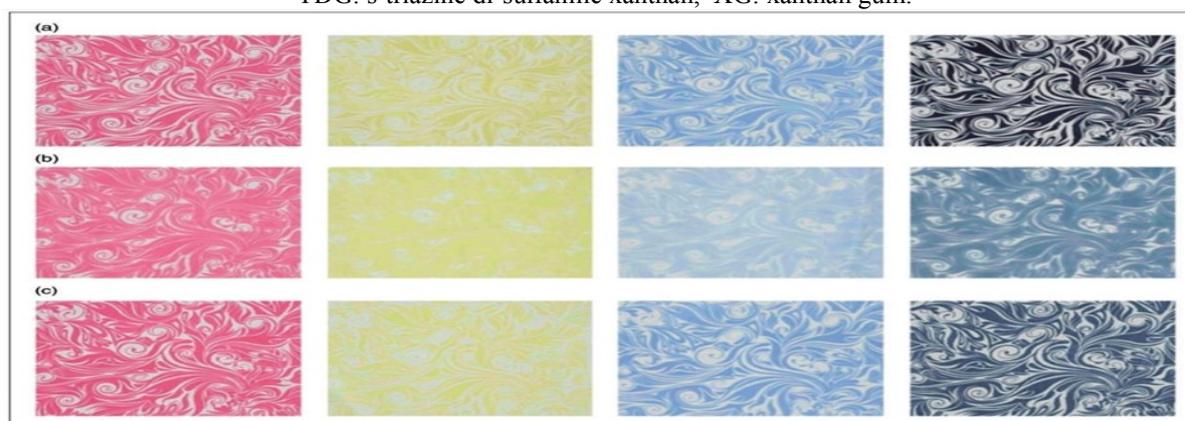


Figure 9. Fine pattern qualities of the printed silk satin using TDG, XG, and SA as thickeners at the same concentration of 3wt % with different reactive dyes.

SA: sodium alginate; TDG: s-triazine di-sulfanilic xanthan; XG: xanthan gum

The TDG value exceeded 90%, indicating a rapid structural recoverability TDG demonstrated greater promise for use as a thickening in screen printing than XG because it had better flowability, more viscous effects, and higher structural recoverability than XG.

The ability of TDG and XG to print on both sides at various concentrations. The effects of double-sided printing on silk fabric varied depending on the rheological properties of the thickening solution at various concentrations.

As shown in Table 8, TDG significantly outperformed XG in terms of paste add-on and color yield (K/S), with 3wt% TDG producing the greatest results, increasing by 90% and 93%, respectively. TDG's PR values went up to more than 90%, illustrating the substance's great penetrability. Additionally, the TDG CVC values were 10% or less, indicating an outstanding color level. But as the concentrations increased, XG's screen ability and levelness significantly declined. It might be explained by the fact that XG's strong elastic

properties prevented successful flow through the screening opening onto the fabric.

Therefore, compared to XG at various concentrations, TDG at various concentrations had considerably better large pattern printing capabilities on silk satin. Additionally, Figure 8 demonstrates that TDG produced different drawing patterns at various concentrations. For XG, low amounts of bleeding phenomenon were observed. The data of XG's VRR showed that XG had a lower viscosity recoverability. The printing paste bled at the designs because the viscosity of XG at low concentrations after shearing did not return to a high level. Due to the poor gel structure of XG, the mesh blockage and breakpoints phenomena only occurred at high concentrations.

TDG's double-sided printing capabilities for huge designs were far better than those of XG before chemical treatment and even beat those of SA. The color yield of TDG on silk satin with reactive red, yellow, blue, and black dyes increased by 29%, 38%, 28%, and 11%, respectively, in comparison to SA. TDG PR values (greater than

90%) performed marginally better than SA PR values. Additionally, as illustrated in Figure 9, the pattern outlines utilizing XG as a thickener were blurry. TDG did, however, achieve distinct outlines akin to SA. TDG has a lot of potential as a thickener on silk fabric with attractive double-sided designs since its ideal double-sided printing characteristics were linked to the appropriate rheological properties.

Application of Xanthan Gum as a Pre-Treatment on Polyester for Inkjet Printing

Inkjet printing on polyester fabric displays versatile environmental advantages. One of the significant benefits of inkjet printing is a dramatic enhancement of the printing quality. In this study, xanthan gum a bio-based thickening agent accompanied by several salts was adopted for the pretreatment of polyester fabric aiming at improving the sharpness and color depth of inkjet printed patterns. The influences of four metal salts (NaCl, KCl, CaCl₂, and MgCl₂) on inkjet printing performance were studied. Results showed that xanthan gum along with a low dosage of bivalent salts can significantly improve the color depth (K/S value) and sharpness of the printed polyester fabrics.

Preparation of Salt-Containing Xanthan Gum :

The mass ratio used to make the xanthan gum paste was 0.3%. With 80°C hot water at 700-900 rpm for one hour, it was swirled and distributed. To the xanthan gum paste, four different salts (NaCl, KCl, CaCl₂, and MgCl₂) were added in turn, each with a different concentration. Before using, the mixture was left overnight after 30 minutes of stirring.

Preparation and printing of Polyester Fabric:

The procedure of preparing saline xanthan gum, inkjet printing on PET fabric, and post-

treatment are shown in Figure 1. Before being dried at 110 °C for 3 minutes, the PET fabric was first padded (hydro-extraction effect was 80%) and dried with various salt-containing xanthan gum solutions using a continuous setting and curing equipment. A commercial dispersion red inkjet ink was used to print with a resolution of 720 * 720 dpi on an inkjet printer. The PET fabric was next dried for three minutes at 110 °C and then placed through a curing fixation procedure for one minute at 190 °C.

The cured PET fabric was ultimately washed in a washing solution with a liquor ratio of 1:30 at 75 °C for 5 minutes using 1 g/L NaOH, 1 g/L sodium hyposulfite, and 1 g/L Detergent LS.

Effect of Salt Concentration(0 : 0.5) on the K/S Value of Inkjet Printing :

- Bivalent salts (Ca²⁺ and Mg²⁺) had a greater effect on the K/S value of inkjet-printed fabric than monovalent salts (Na⁺ and K⁺). The K/S value of inkjet printed fabric rises as salt concentrations rise.
- Salt concentration (x/mol.L⁻¹) and K/S value (y) are correlated. When salt concentrations ranged from 0.01 to 0.2 mol/L, the K/S value significantly increased in comparison to salt-free xanthan gum solutions. The K/S value exhibits a relationship with salt concentration (x/mol.L⁻¹).
- The sequence of the cation salts is Ca²⁺ > Mg²⁺ > Na⁺ > K⁺ as the K/S value declines.
- With the addition of inorganic cations, the apparent viscosity, and viscoelasticity of XG solutions decrease [43]. By adding surfactants and salt, one can adjust the viscoelastic and morphological characteristics of xanthan [44].

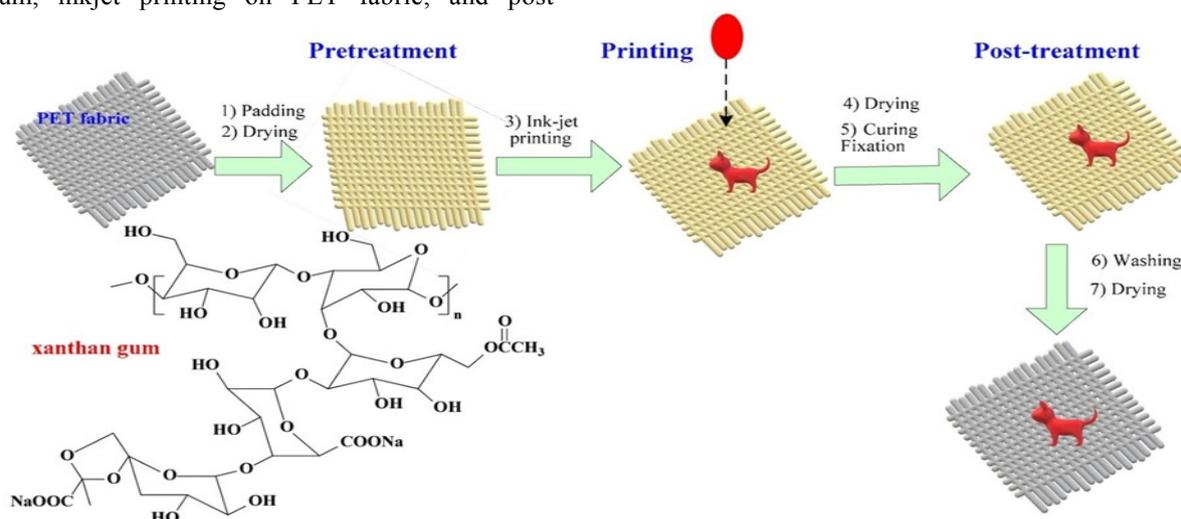


Figure 10: Flowchart of the printing process on the pretreated polyethylene terephthalate (PET) fabric.

- The pretreatment of inkjet printing is better suited to xanthan gum with bivalent salt because it is simple to absorb and permeates with low viscosity. Additionally, the salt has the effect of lowering the potential of the double layer and fiber surface, which can assist in reducing the electrostatic repulsion of the dye with the fabric surface (xanthan gum), encourages the dye's absorption and fixation with the fibers, and also enhances dry rubbing fastness grade and apparent color gain of the dye.

The k/s of treated PET fabric using 0.1 mol/l CaCl_2 and 0.3% xanthan gum was higher than that of treated PET fabric just using 0.3% xanthan gum under the best pretreatment conditions; it can be calculated that the k/s increased by 26.99%. The CaCl_2 and xanthan gum-treated pet fabric's color fastness grades were 4-5 (dry rubbing), 4-5 (washing), and 5 (light), respectively.

- The treated PET fabric utilizing CaCl_2 had a higher dry rubbing fastness grade than that produced using simply xanthan gum. (The grade of drying rubbing fastness was 4)
- According to information, water-soluble xanthan gum can be easily removed from cloth by washing it after post-treatment. Due to its water solubility and simplicity of washing, xanthan gum did not affect the microstructural characterization of PET fibers. In actuality, 88.96% of the xanthan gum was removed during post-treatment. The air permeability of the fibers was 313.3 mm/s, which was almost as high as the permeability of untreated PET fibers.
- xanthan gum and salt pre-treatment of polyester fabric can enhance the color depth and printing clarity of inkjet printing, and divalent salt can provide greater K/S values and printing clarity. K/S increased by 26.99% when pretreatment conditions with 0.1 mol/L calcium chloride and 0.3% xanthan gum paste were used as opposed to those without.

Conclusions

Extracellular polysaccharide produced by the bacterium *Xanthomonas* sp. xanthan gum is employed as a thickening agent in the food and textile industries as well as an emulsifier in a wide range of industrial processes. It is also effective in secondary oil recovery activities. However, due to its stiffness and ordered conformation, when used as a thickener, XG showed greater elastic behavior, weak gel properties, and printing flaws such as poor

screen ability, low color yield, and uneven color. Therefore, whether XG solutions' rheological characteristics are altered through modification techniques to provide desirable printing effects. The results showed that as the degree of modification of modified xanthan gums increased, so increased their flowability and vicious impact. MXG and TDG were used instead of xanthan gum for reactive dye printing on cotton and silk fabrics, resulting in significantly higher screenability, colour yield, penetration, and outline sharpness than XG. XG was also used as a thickening agent in addition to a number of salts for the pretreatment of polyester fabric with the purpose of improving the sharpness and colour depth of inkjet printed patterns.

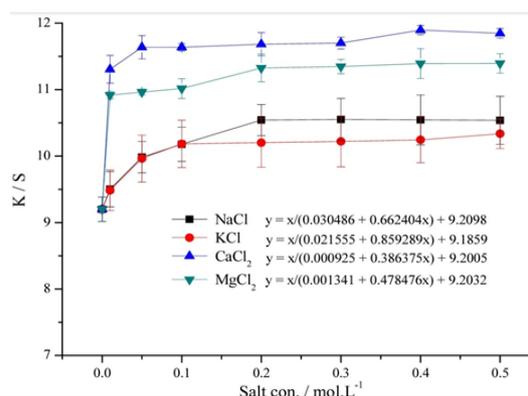


Figure 11 shows the K/S value of the inkjet ink-printed fabric treated with four kinds of saline xanthan gum. Salt concentrations were varied in the range of 0–0.5 mol/L.

Conflict of Interest

There is no conflict of interest in the publication of this article.

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استخدام صمغ الزانثان المعدل كمثخن في طباعة الأقمشة الطبيعية والصناعية

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المستخلص صمغ الزانثان ، أحد أفراد عائلة مواد التكتيف الطبيعية ، نمت فائدته في التطبيقات الغذائية والصناعية. ومع ذلك ، عند استخدامه كمكثف ، أظهر Xanthan Gum سلوكاً أكثر مرونة وخصائص هلام ضعيفة بسبب صلابته والتشكيل المنتظم ، بالإضافة إلى عيوب الطباعة مثل ضعف قدرة الشاشة وانخفاض إنتاجية اللون واللون غير المتساوي. إذا تم استخدام تقنيات التعديل لتغيير الخصائص الانسيابية لحلول XG من أجل الحصول على نتائج طباعة فعالة ، فقد اشتمل هذا العمل على نزع أسيتيل العديد من صمغ الزانثان المعدل (MXG) باستخدام معالجة قلووية عند درجة حرارة معينة على الأقمشة القطنية والحريرية واستخدامها معالجة مسبقة لأقمشة البوليستر. تم تحسين قدرة الشاشة وإنتاجية اللون واختراق الطباعة عند استخدام MXG كمكثف بدلاً من صمغ الزانثان. حققت هذه المكثفات أداء طباعة ممتازاً ، والتي قد تكون معاجين جيدة لتلبية متطلبات الطباعة على القطن والحرير والبوليستر

الكلمات المفتاحية: صمغ الزانثان ، صمغ الزانثان المعدل ، طباعة المنسوجات.