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Microwave assisted chemical modification of starch in presence or absence of amylase enzyme and its application in textile printing

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ABSTRACT

The main aim of the current work is to investigate the influences of microwave irradiation (in absence of α-amylase enzyme) on the properties of different kinds of starches namely maize (MS), rice (RS), and wheat starch (WS). To achieve this goal. Starch was subjected to microwave irradiation in the absence of enzyme namely α-amylase under different conditions. The latter comprise is the starch concentration, time, and temperature of microwave irradiation. Furthermore, starch was subjected to microwave irradiation in the presence of enzyme under different conditions too. The latter comprises the concentration of enzyme and power level (watt) of microwave irradiation. The influence of these treatments on both the solubility as well as rheological properties of treated starches was thoroughly evaluated. Moreover, the visibility of using these treated starches as a thickening agent in burn-out printing style in printing paste was also investigated. The results of these investigations demonstrated that the optimum condition was found to be 10g starch (irrespective of the starch nature) in 100 ml water at pH 7 then added 0.2 ml of α-amylase enzyme. The mixture was cured at 55°C for 3 minutes at 30 watts under microwave irradiation. Also, the obtained result showed that at a constant rate of shear the apparent viscosity increases by increasing the concentration of starch, temperature as well as time of treatment, irradiation of starches in presence of enzyme convert the rheological properties of starches from non-Newtonian thixotropic into non-Newtonian pseudoplastic. The prepared pastes were successfully used in printing wool/polyester (45/55) or wool/nylon (70/30). Where the loss in weight of the burn-out printed wool/polyester or wool/nylon is slightly higher on using modified starches compared with mypro gum. The color fastness of printed sample for rubbing, washing and perspiration was evaluated.

Keywords: *Maize starch; Enzymes; Microwave; Burn-out, Textile printing.*

1. INTRODUCTION

Textile processing consumes massive amount of energy as in dye fixation and heat setting. Saving processing time and energy is of immediate interest to textile industry. The introduction of new techniques which will allow less energy, time as well as water to be used is a highly significant area of activity to consider. Many researchers are interested in finding out novel technologies to achieve quality, time saving, reduce energy consumption and eco-friendly processing [1-5]. One of these new technologies is known as "microwave technology" which could be used in different textile processes such as finishing [6], dyeing [7], printing [8-10] and wet processes [11] while achieving the targets mentioned above. A relatively short section of property designed microwave heating can increase production speeds [12].

In microwave treatment, the material supplied energy directly by an electromagnetic field, which leads to rapid heating throughout the material thickness with reduced thermal gradients. There is another type of heating can also save time and energy called "Volumetric heating ". The microwave field as well as the dielectric heating response of material govern its ability to heat with microwave energy [13-15]. It is essential to know electromagnetic theory and dielectric heating, to optimize the processing of materials through microwave heating. Fig (1) shows the different heating techniques: (a) conventional heating and (b) microwave irradiation.

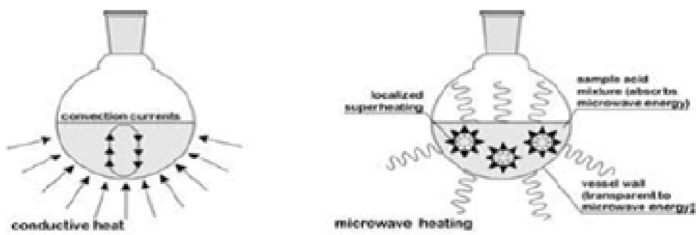

Figure 1. Different heating technique: (a) conventional heating, (b) microwave irradiation.

Microwave heating is based on many parameters such as dielectric heating, the ability of some polar liquids and solids to absorb and convert microwave energy into heat. In this situation, a considerable property is the mobility of the dipoles by ionic conduction, dipolar polarization and the ability to orient them according to the direction of the electric field. The orientation of the dipole's changes with the magnitude and the direction of the electric field [16-19]

Because volumetric heating is un-dependent on heat convey by conduction or convection, it is conceivable to use microwave heating for implementation where convective heat transfer is inappropriate. For example, it is in heterogeneous fluids where the similar heating of solids and liquids is required to reduce over processing. Another example is for obtaining very low final moisture levels for product without over-drying [20].

The existing work aims to investigate the improvement of microwave in modification of starch in presence or absence of amylase enzyme. Furthermore, the microwave irradiated starches in presence of α-amylase enzyme were successfully used as thickening agent in burn-out printing of both wool/polyester and wool/nylon blends.

2. MATERIALS AND METHODS

2.1. Materials.

2.1.1. Fabric.

Wool/polyester (45/55) blended fabric, and wool/nylon blended (70/30) blended fabric produced by El-Mehalla for Spinning and Weaving Company.

2.1.2. Starch.

2.1.2.1. Egyption maize starch suplied by Misr Company for Starch and Glucose, Cairo,

2.1.2.2. Egypt. Egyption rice Starch suplied by the Egyption Starch Yeast and Detergent

2.1.2.3. Company, Cairo, Egypt. Egyption Wheat Starch from the local Egyption Market.

2.1.3. Thickening agent:

2.1.3.1. Mypro gum NP-16, a non-ionic chemically modified Guar endosperm derivative, kindly supplied by Meyhall chemical AG Switzerland, was use.

2.1.3.2. **Sodium alginate** of medium viscosity type manufactured by Ceca Kollad chemie (Paris- france) was kindly supplied under the commercial name Cecalginate HV/KL 600.

2.1.3.3. Daico thickener 1600, synthetic thickener was kindly supplied by Daico Company, Cairo, Egypt.

2.1.4. **Dyes.**

2.1.4.1. ***Disperse dyes****: Dianix Classic orange SE-R, supplied by Dystar, Cairo, Egypt.*

2.1.4.2. ***Reactive dyes:*** *Procion Red PX-8B, supplied by Dystar, Cairo,Egypt.*

2.1.5. Chemical.

Sodium hydroxide, Sodium dihydrogen phosphate, Sodium chlorate and Glycerin as well as commercial ethyl alcohol (95%) were used.

2.1.6. Enzyme**:**

Alpha-amylase enzyme, supplied by Novozymes A/S Krogshoejvej 362880 Bagsvaerd Denmark.

2.2. Methods.

a) Starch modification in absence of enzyme

In this respect microwave were used as a source of heating to attain gelatinization under different experimental conditions. This latter comprises starch concentration (7.5, 10 and 12.5g/100 ml water) at different temperatures (55, 60, 65 and 70°C) for different intervals of time (2, 3, 4 and 5 min).

b) Starch modification in presence of enzyme

Starch was subjected to enzymatic modification via adding amylase enzyme followed by subjecting to microwave irradiation under different conditions. The latter comprises the amount of enzyme and power to obtain pastes acquired a suitable viscosity, and the rheological properties of the pastes were measured.

After enzymatic modification the modified starch samples were precipitated using ethyl alcohol and finally subjected to purification via dissolving in water and precipitation again in ethyl alcohol to remove the remaining of the enzyme. At this end the modified starches were dried at the ambient temperature.

2.2.1. Preparation of the printing paste.

2.2.1.1. Burn-out printing:

2.2.1.1.1. Burn-out printing of wool/polyester blend:

Burn-out printing of wool/polyester blend was achieved via printing of the blended fabrics using printing pastes containing the following recipe:

Thickening agents	X g/Kg
Sodium hydroxide	250g/Kg
Glycerin	50g/Kg
Water	Y
Total	1000g

Thickening agents used were mypro gum (80g/Kg) printing paste coupled with microwave irradiated enzymatic hydrolyzed starches (170g/Kg) printing paste.

Fixation.

The burn-out printed wool/polyester blended fabrics were fixed via steaming at 102°C for 10 min.

Washing.

The burn-out printed wool/polyester blended fabrics were washed with cold water + dilute acetic acid solution.

2.2.1.1.2. Over printing.

Using disperse dye:

The remaining portion of polyester from the burn-out printed wool/polyester blend fabrics were subjected to over printing using disperse dye according to the following recipe:

Disperse dye namely Dianix Classic orange SE-R	30g
Thickener	X
Lyo print	3g
Sodium dihydrogen phosphate	5g
Sodium chlorate	10g
Water	Y
Total	1000g

The amount of thickener used was 30g/Kg printing paste Daico-thic. The paste was adjusted at pH 5.

After printing the samples were fixed via steaming at 102◦ for 30 min, and then the samples were washed in cold water.

Finally, the blended wool/polyester fabrics which have been over printed using disperse dye were subjected to washing and reduction clear using sodium hydroxide 4g/l, sodium hydrosulphite 2g/l and detergent 1g/l.

2.2.1.2. Burn-out printing of wool/nylon blend:

Burn-out printing of wool/polyester blend was achieved via printing of the blended fabrics using printing pastes containing the following recipe:

Thickening agents	X g/Kg
Sodium hydroxide	250g/Kg
Glycerin	50g/Kg
Water	Y
Total	1000g

Thickening agents used were mypro gum (80g/Kg) printing paste or microwave irradiated enzymatic hydrolyzed starches (170g/Kg) printing paste.

Reactive dye namely Procion Red PX-8B	30g
Urea	50g
Thioethylene glycol	50g
Thickener	X
Water	Y
Formic acid 85%	10
Sodium chlorate 1:2	15
Total	1000g

***Fixation**:*

The burn-out printed wool/polyester blended fabrics were fixed via steaming at 102°C for 10min.

Washing:

The burn-out printed wool/polyester blended fabrics were washed with cold water +dilute acetic acid solution.

Over printing

Using reactive dye:

The remaining portion of nylon from the burn-out printed wool/nylon blend fabrics were subjected to over printing using reactive dye according to the following recipe:

The amount of thickener used was 40g/Kg printing paste sodium alginate.

After printing the samples were fixed via steaming at 102◦C for 30min. then the samples were washed in cold water and soaping of the prints with 2g/l non-ionic detergent at 60°C for 30min.

2.3. Rheological properties.

The rheological properties expressed as apparent viscosity at different rates of shear were measured using Brookfield Model DV-111 programmable Rheometer.

2.4. Fastness properties.

Fastness properties to washing, rubbing (dry &wet), perspiration as well as light fastness were measured according to a standard method [21].

3. RESULTS

The current work aims to chemical modified of starch in absence and/or presence of α-amylase enzyme coupled with microwave irradiation, and investigate the effect of microwave irradiation on the properties of obtained starch. To achieve this goal, MS were subjected to microwave irradiation in absence and/or in presence of α-amylase enzyme under different conditions. The latter comprise the starch concentration, time, temperature and power level (watt) of microwave irradiation. Given below the condition of microwave irradiation and its influence on the rheological properties as well as solubility of starch.

3.1. Effect of Starch amount.

To investigate the effect of starch amount, different amounts of MS 7.5, 10 and 12.5g were added to 100 ml of water at pH 7 at ambient temperature. The temperature was raised to 55°C under vigorous stirring under microwave irradiation. The mixture was left for 3 minutes at 55°C. After which, the obtained cooked starches were cooled and its apparent viscosity at various rates of shear was measured according to the method indicated in the experimental section. The results obtained are given in Table **1.**

Table 1. Effect of microwave irradiation MS at different starch amount on the apparent viscosity at different rates of shear.

Conc. of Starch g/100 ml	Solubility in cold water	Apparent Viscosity in centipoise at rate of shear (sec^{-1})				
		6.80	10.2	13.6	17	20.4
7.5	Partial soluble	475	435	390	364	305
10.0	Partial soluble	520	470	420	397	341
12.5	Partial soluble	580	530	500	477	430

It is clear from the data of table **1** that as the amount of starch increases from 7.5 to 10 to 12.5%, the apparent viscosity increases regularly irrespective of the rate of shear, while it decreases as the rate of shear increases. For example if the rate of shear is held constant at 6.80 sec^{-1} the apparent viscosity increases from 475 to 520 to 580 centipoise by increasing the concentration of starch from 7.5 to 10 to 12.5 g% respectively fig. 1, 2. On the other hand, the cooked starch is partial soluble in cold water.

This may be attributed to microwave heating mechanism, when using imitative heating source, as water bath, for starch cooking, heat will take place from the exterior surface into the interior of the starch, so the cooking process will be slow and ineffectual for transferring heat into the system, because it depends on the ability of thermal conductivity that can penetrate into the materials, and the result is the reaction vessel has higher temperature than that of the reaction mixture. On contrary, microwave produces effective internal heating (in core, these phenomena known as volumetric heating) by direct coupling of microwave heating with the starch molecules in the reaction mixture, which lead to homogenies in reaction medium and prevent the oligomer [22].

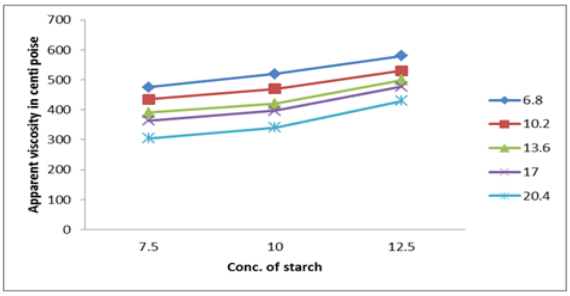

Figure 1. Effect of microwave irradiation MS amount on the apparent viscosity at different rates of shear.

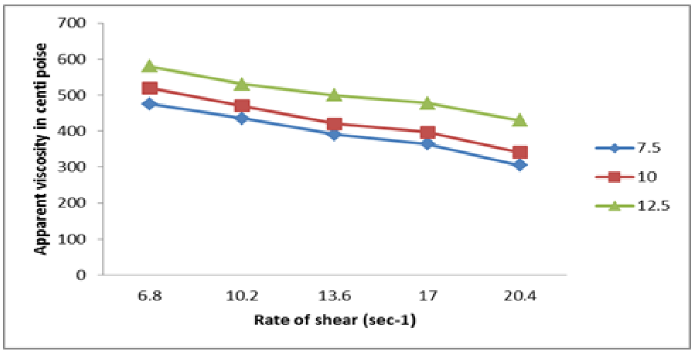

Figure 2. D[1]ependence of the apparent viscosity on the conc. of MS and rate of shear.

3.2. Effect of Temperature of microwave irradiation on the viscosity of MS.

To investigate the effect of microwave irradiation at different degree of temperature on maize starch. 10g of MS were added to 100ml water at pH 7.

Table 2. Effect of microwave temperature on the viscosity of maize starch.

Temp /°C	Solubility in cold water	Apparent Viscosity in centipoise at rate of shear (sec^{-1})				
		6.80	10.2	13.6	17	20.4
55	Partial soluble	475	435	390	364	305
60	Partial soluble	654	600	560	500	450
65	Partial soluble	724	672	630	560	515
70	Partial soluble	790	734	675	628	571

The temperature of microwave was varied from 55, 60, 65 and 70°C and left at this temperature for 3 minutes. After this, the samples were cooled at room temperature and the viscosity was measured at different rates of shear. The results obtained are given in Table **2** and represented in Figures 3 and 4.

It is clear from the data of table **2** that the apparent viscosity depends on the temperature attain occur during microwave irradiation of starch slurry. As the temperature of microwave irradiation increase the apparent viscosity increases regularly irrespective of the value of rate of shear and vies-versa as the rate of shear increases the apparent viscosity decreases. For example, it increases from 475 to 654 to 724 to 790 centipoises by increasing the temperature from 55° to 60° to 65° to 70°C respectively when the rate of shear is held constant at 6.80sec^{-1}. While it increases from 305 to 450 to 515 to 571 centipoises at rate of shear of 20.4 sec^{-1}.

The increase in the apparent viscosity by increasing the temperature of microwave irradiation may be due to the improvement in solubility and/or the increase in the adhesive properties of starch. As the adhesive properties increases. The resistance to flow increases and hence the viscosity increases.

This is attributed to another advantage for microwave irradiation, microwave has a distinctive advantage, it using selective heating of materials, the ability of the microwaves to interact with materials and transfer energy affects by molecular structure. When interact materials have dielectric properties, couple with the higher loss material will selectively by microwaves [23, 24]. Microwaves can able to initiate chemical reactions through selective heating of reactants; so, new materials may be formed, which is not possible in classical processing.

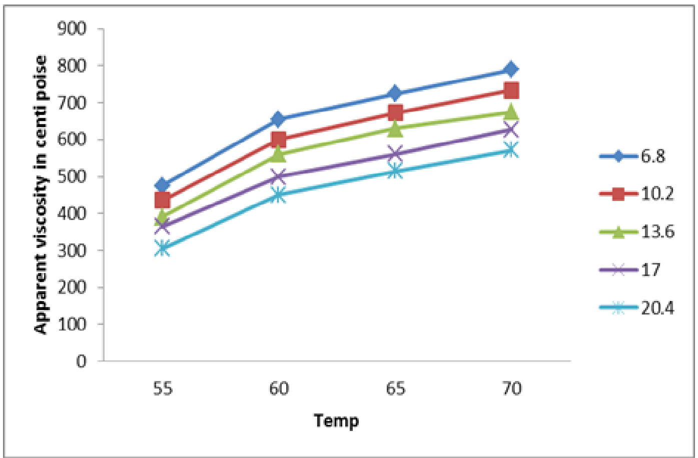

Figure 3. Effect of Temperature on the viscosity of maize starch.

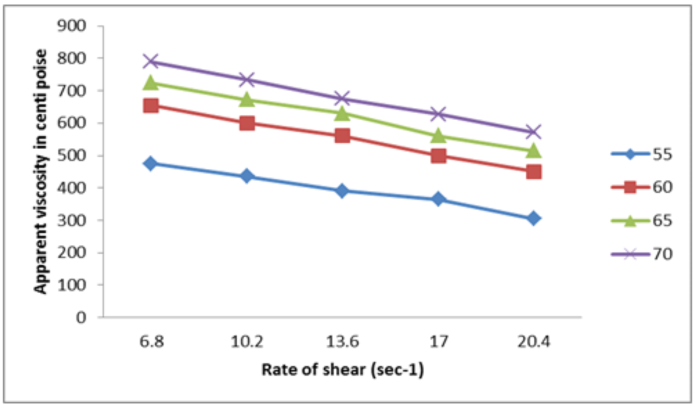

Figure 4. Dependence of the apparent viscosity on temperature and rate of shear.

3.3. Effect of Time of microwave irradiation on the viscosity of maize starch.

To investigate the effect of time of microwave irradiation on the properties of maize starch.10g of starch were added to 100 ml water, after that the pH was adjusted to pH 7. The temperature was raised to 55°C and the mixture was kept for 2, 3, 4or 5min while the temperature maintains constant at 55°C.

After that, the mixture was left to cool at room temperature and its viscosity was measured. The data obtained are given in Table **3** and represented in figures 5 and 6.

Table 3. Effect of Time of microwave irradiation on the viscosity of maize starch.

Time/ min	Solubility in cold water	Apparent Viscosity in centipoise at rate of shear (sec^{-1})				
		6.80	10.2	13.6	17	20.4
2	Partial soluble	324	298	273	233	183
3	Partial soluble	475	435	390	364	305
4	Partial soluble	739	707	674	626	530
5	Partial soluble	842	813	774	738	698

It is clear from the data of Table **3** that as the time of reaction increases the apparent viscosity increase also. This phenomenon holds true at any specific rate of shear. For example, at a rate of shear of 10.2sec^{-1} it increases from 298 to 435 to 707 to 813 centipoise by increasing the irradiation time from 2 to 3 to 4 to 5 min respectively.

The increase in viscosity by increasing the time of exposure to microwave irradiation may be also due to the increase in the solubility and adhesive properties of maize starch under the influence of microwave irradiation.

When imitative heating is utilized, considerable time and energy are wasted to heating up the interface by conduction through the materials. While, when using microwaves, the joint interface can be heated in-situ by amalgamate a higher loss material at the interface [25]. In multiple stage materials, some stages may couple more easily with microwaves. Consequently, it may be possible to produce materials with new or individual microstructures by selectively heating distinct stage which leads to saving time and energy.

3.4. Effect of Enzyme Concentration.

In the previous work starch was subjected to microwave irradiation in absence of α-amylase enzyme. To investigate the effect of irradiation with microwave in presence of different concentrations of enzyme. 10g of maize starch was added to 100ml water mixed well, different concentrations of amylase enzyme (0.1, 0.2, 0.3 and 0.4ml) were added. The temperature was raised to 55°C. The mixture was left at 55°C for 3min, after which it is left to cool and its viscosity was measured the results obtained are represented in Table **4** and illustrated in Figures **7** and **8**.

It is clear from the data Table **4** Figures **7** and **8** that the apparent viscosity of the enzymatic modified maize starch depends on both the concentration of amylase enzyme and the rate of shear at which the viscosity is measured.

As the concentration of enzymes increases from 0.1 to 0.2 to 0.3 to 0.4 ml / 100ml water the apparent viscosity decreases. However, the magnitude of decreasing depends on rate of shear. For example, at a rate of shear of 13.6 sec^{-1}., the apparent viscosity decreases from 277 to 243 to 23.7 to 13 by increasing the enzyme concentration from 0.1 to 0.2 to 0.3 to 0.4 ml respectively. On the other hand, as the rate of shear increases the apparent viscosity decreases.

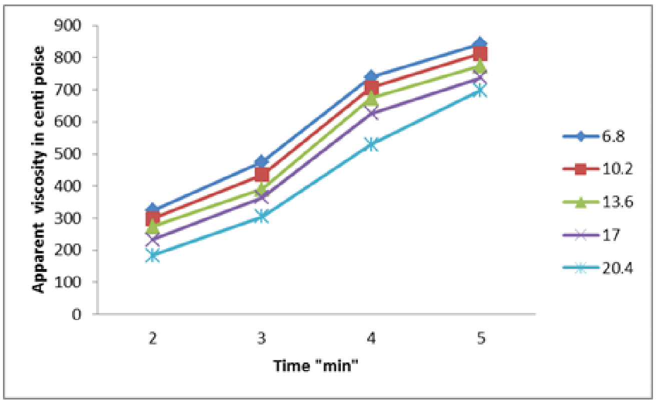

Figure 5. Effect of Time on the apparent viscosity of starch.

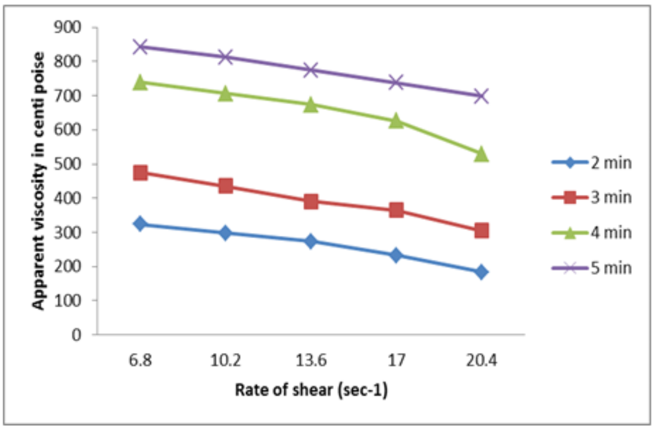

Figure 6. Dependence of the apparent viscosity on time and rate of shear.

Table 4. Effect of amylase concentration on the apparent viscosity of maize starch.

Conc. Of Enzyme/ ml	Solubility in cold water	Apparent Viscosity in centipoise at rate of shear (sec^{-1})				
		6.80	10.2	13.6	17	20.4
0.1	Soluble	377	316	277	216	183
0.2	Soluble	305	275	243	190	140
0.3	Soluble	34	27	23.7	18.8	15
0.4	Soluble	25	17.5	13	10	8.33

It is also clear from the data of table 4 that the rate of hydrolysis of starch by α-amylase is very fast under the influence of microwave irradiation. This is clear from both: a) the remarkable drop in values of the apparent viscosity at any specific rate of shear, b) the improvement of the solubility of starch where it converted to cold water soluble.

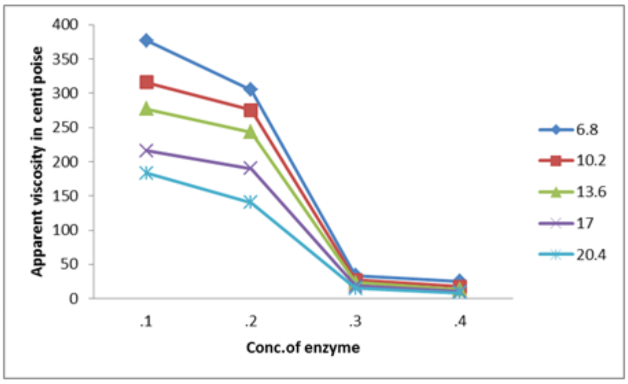

Figure 7. Effect of amylases concentration on the apparent viscosity of modified starch under microwave irradiation.

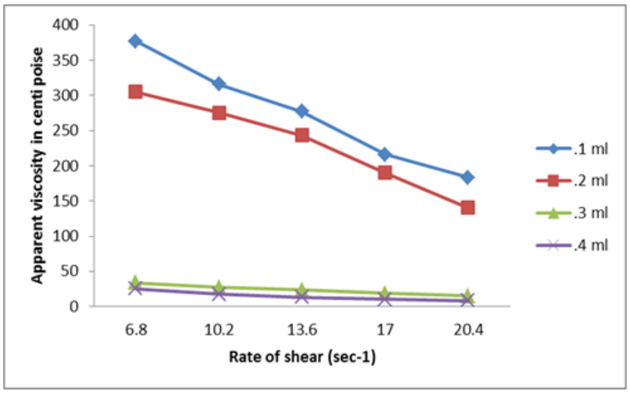

Figure 8. Dependence of the apparent viscosity on the conc. of enzyme and rate of shear.

3.5. Effect of microwave power level on the properties of maize starch.

Finally, it is of great interest to investigate the effect of microwave power on the properties of maize starch to achieve this, 10g of maize starch was added to 100ml water containing .2ml amylase enzyme mixed well. The power was raised to 30, 40, 50 and 60. After which it is left to cool and its viscosity was measured the results obtained are represented in Table **5** and illustrated in Figures 9 and 10.

Table 5. Effect of power on the viscosity of maize starch.

Power/ Watt	Solubility in cold water	Apparent Viscosity in centipoise at rate of shear (sec^{-1})				
		6.80	10.2	13.6	17	20.4
30	Soluble	573	530	496	445	407
40	Soluble	275	242	217	183	150
50	Soluble	222	165	155	123	110
60	Soluble	180	148	130	117	105

Microwave irradiation depend on dielectric heating phenomenon, some polar liquids (H_2O) and solids (starch) have the ability to absorb and convert microwave energy into heat. The orientation of the dipoles depends on the magnitude and the electrical field direction. Through rotation, molecules that have a permanent dipole moment can align themselves completely or at least partly, with the direction of the field. Therefore, energy is lost in a variety of heat through molecular friction and dielectric loss. The amount of heat produced by this method is directly associated with the aptitude of the matrix to align itself with the frequency of the applied of electric field [26, 27].

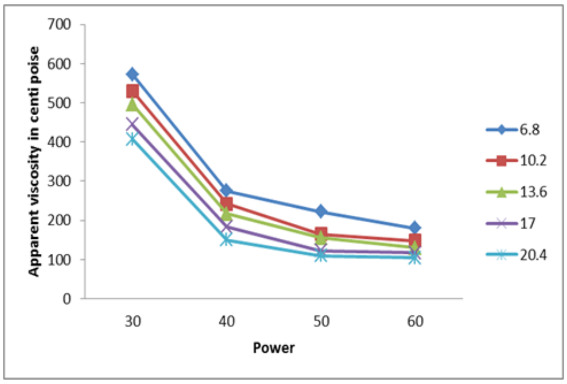

Figure 9. Effect of power on the apparent viscosity of maize starch.

Here too the apparent viscosity depends on: a) the magnitude of microwave power level and b) the rate of shear at which the viscosity was measured. Increasing the power of microwave irradiation from 30 to 60 decreases the apparent viscosity from 573 to 180 and from 407 to 105.

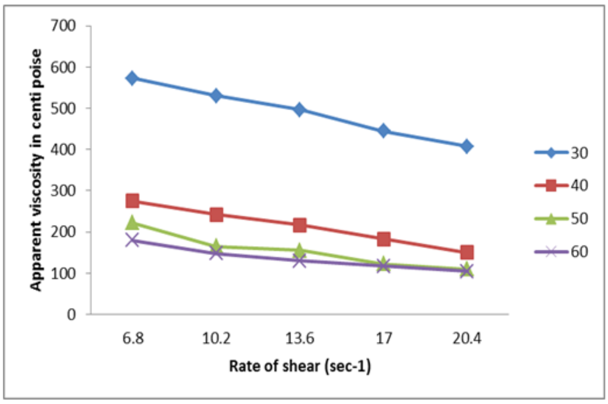

Figure 10. Dependence of the apparent viscosity on the power and rate of shear.

3.6. Printing.

Samples of maize, rice and wheat starches were modified under these optimum conditions using 10g starch in 100 ml water at pH 7 followed by addition of 0.2 ml α-amylase enzyme. The mixture was mixed well and the temperature of microwave was raised to 55°C. The reaction mixture was left at 55°C for 3 minutes at 30 watts via microwave irradiation. After that the samples were precipitated in commercial ethyl alcohol, purified in Soxhlet using 75% ethyl alcohol and finally air dried. The dry modified starches were evaluated as thickening agents in burn-out printing. To achieve this goal, printing pastes thickened with α-amylase enzyme treated starch samples were prepared (using either maize, rice or wheat starch) according to the recipe indicated in the experimental section. For the sake of comparison, other pastes thickened with sodium alginate and/or daico-thic were also prepared. After printing, drying of the printed goods the fixation was carried out via steaming under the mentioned experimental conditions indicated for each kind. The loss in weight% was measured for the burn-out printed polyester/wool and/or nylon/wool blended fabrics, Also, the K/S and overall color fastness properties were measured for the screen printed fabrics over printed after removal of the burn portion of the blend. Given below the results obtained along with the appropriate discussion.

3.6.1. Burn-out printing:

The microwave irradiated starches in presence of α-amylase enzyme were evaluated as thickening agents in burn-out printing style. To achieve this goal. Burn-out printing paste containing sodium hydroxide (250g/kg paste) and thickened with either enzymatic treated starch samples or mypro gum were prepared. The prepared pastes were used in printing wool/polyester (45/55) or wool/nylon (70/30).

Table 6. Effect of thickener type on weight loss % of burn-out printed wool/ polyester blended fabrics.

Thickener type	Weight loss %
Mypro gum	66.6
Treated Maize starch	77.7
Treated Rice starch	72.2
Treated Wheat starch	72.2

After printing and drying, the samples were either steamed at 102°C for 15 minutes. After that the samples were washed thoroughly, air dried and assessed for weight loss.
The results obtained are given in Tables **6** and **7** for wool/polyester and wool/nylon respectively.

Table 7. Effect of thickener type on weight loss % of burn-out printed wool/ nylon blended fabrics.

Thickener type	Weight loss %
Mypro gum	81.8
Treated Maize starch	88.6
Treated Rice starch	86.3
Treated Wheat starch	86.3

It is clear from the data of tables **6** as well as table **7** that microwave irradiated enzymatic modified starches could be used successfully as thickening agents in burn-out printing style of both wool/ polyester or wool/nylon blended. The % loss in weight depends on the nature of the thickening agent used follows the order: the % loss in weight on using modified maize starch > rice or wheat starches > mypro gum.
It can be concluded that enzymatic treated starch especially maize starch could act successfully as thickening agent in burn out printing of wool/polyester blend or wool/nylon blend.

3.6.2. Overprinting of burn-out printed wool/polyester blended fabrics:

The aforementioned burn-out printed samples were subjected to printing using disperse dye namely Dianix Classic orange SE-R. After printing, drying, fixation, washing and drying the samples were assessed for K/S and overall fastness properties, the results obtained are represented in table 8**.**

Table 8. Properties of the over printed burn-out of wool/polyester blended fabrics on using starch treated with α-amylase enzyme as well as commercial Daico-thickener.

Thickener Used	K/S	Washing fastness		Rubbing fastness		Perspiration fastness			
						Acidic		Alkali	
		St.	Alt.	Dry	Wet	St.	Alt.	St.	Alt.
Untreated	18.36	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4
Sodium-alginate	11.77	4	4	4-5	4	4	4	4	4
Treated maize starch	9.98	4-5	4-5	4-5	4-5	4-5	45	4-5	4-5
Treated rice starch	9.15	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Treated wheat starch	10.48	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5

It is clear from table 8 that on using disperse dye namely Dianix Classic orange SE-R.the K/S of the burn-out printed samples using modified starches followed by coloured printing paste containing the color and daico-thickener as a thickening agent depends on the original thickening agent used in uncolored discharge printing paste, i.e. modified starch, where removed portion of the blend expressed as loss in weight % was found to depend on the nature of the used starch thickener.
Table **8** comprises too the data of color fastness properties. It is clear that all the samples are nearly acquire equal all over color fastness properties.

4.1.2. Overprinting of burn-out printed wool/nylon blended fabrics:

Table 9 represent the results obtained on over printing of wool/ nylon after burn-out printing using sodium hydroxide.

The results of these investigations can be summarized in the following:

Irrespective of the nature of starch the optimum condition was found to be 10g starch in 100 ml water at pH 7 followed by addition of 0.2 ml α-amylase enzyme. The mixture was mixed well and the temperature of microwave was raised to 55°C and left at this temperature for 3 minutes at 30 watts.

At a constant rate of shear the apparent viscosity increases by increasing the concentration of starch, temperature and time of treatment.

Table 9. Properties of the over printed burn-out printed wool/nylon blended fabrics on using starch treated with amylase enzyme as well as commercial sodium alginate.

Thickener Used	K/S	Washing fastness		Rubbing fastness		Perspiration fastness			
						Acidic		Alkali	
		St.	Alt.	Dry	Wet	St.	Alt.	St.	Alt.
Untreated	17.83	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4
Daico thickener	21.80	3-4	3-4	4-5	3-4	3-4	3-4	3-4	3-4
Treated maize starch	22.65	4	4	4-5	4	4	4	4	4
Treated rice starch	24.49	4	4	4-5	4	4-5	4	4-5	4
Treated wheat starch	22.71	4	4	4-5	4	4	4	4	4

Irradiation of starches in presence of enzyme converts the rheological properties of starches from non-Newtonian thixotropic into non-Newtonian pseudoplastic.

The microwave irradiated starches in presence of α-amylase enzyme were evaluated as thickening agents in burn-out printing style. To achieve this goal. Burn-out printing paste containing sodium hydroxide (250g/kg paste) and thickened with either enzymatic treated starch samples or mypro gum were prepared. The prepared pastes were successfully used in printing wool/polyester (45/55) or wool/nylon (70/30). Where the loss in weight of the burn-out printed wool/polyester or wool/nylon is slightly higher on using modified starches compared with mypro gum. While the overall color fastness properties are nearly the same.

4. CONCLUSIONS

The main aim of the present work is to investigate the influence of microwave irradiation (in absence or presence of α-amylase enzyme) on the properties of different kinds of starches. To achieve this goal. Starch was subjected to microwave irradiation in absence and/or in the presence of α-amylase enzyme under different conditions. The latter comprises the concentration of starch, time, and temperature of microwave irradiation. Furthermore, starch was subjected to microwave irradiation in presence of enzyme under different conditions too. The latter comprises the concentration of enzyme and power level of microwave irradiation. The influence of these treatments on both the solubility and rheological properties of treated starches were thoroughly investigated.

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