International Journal of Modern Science and Technology, 2019;4(11):286-293.
ISSN: 2456-0235.
www.ijmst.co

Research Article

Valuation of Polyvinyl alcohol and Maize Starch as Sizing Agent for Textile processing

Derseh Yilie Lemeneh, Addisu Ferede Tesema

Ethiopian Institute of Textile and Fashion Technology,
Bahir Dar University, Bahir Dar, Ethiopia.

*Corresponding author's e-mail: derseh2003@gmail.com

Abstract

Weaving efficiency is affected by a number of factors of which the main being warp breakage rate. These warp breakages can be reduced by sizing the warp yarns with either natural or synthetic sizing agents. Most industries in Ethiopia uses maize starch as sizing agents affecting their weaving efficiency and the quality of fabric they produced. In the present work, polyvinyl alcohol (PVA) and maize starch sizing agents were compared on quality of sized yarns, weaving efficiency and the cost of sizing recipe. Cotton yarns were sized using both sizing agents after which different yarn and fabric properties were tested. Desizing was done enzymatically and its outcome also tested for both sizing agents. The ease of size removal, cost of the size recipes and weaving efficiency were also compared. From all factors considered, PVA sizing agent confirmed to be superior to maize starch in respect to yarn quality produced and the cost of size recipe.

Keywords: Sizing, Polyvinyl Alcohol, Maize Starch, Desizing agents, Enzymatic Desizing.

Introduction

Warp yarns undergo various forces during the weaving process which can lead to breakages thus affecting the weaving efficiency. To reduce the effect of these forces, the warp yarns are sized before weaving. Sizing is a reputable way of enhancing the weavability of textile yarns. Sizing is the process of coating or impregnating warp yarns with a polymer that improves the efficiency of the weaving operation by reducing the incidences of warp breakages during the weaving process [1]. Starch has been the most popular and economical sizing agent in the textile industry. Natural starch and its derivatives still constitute nearly 75% of the sizing agents used in the textile industry throughout the world and remains the predominant ingredient in most types of sizes [2, 3]. Synthetic sizing agents have also been developed to improve weaving efficiency. Some of these synthetic sizing materials have got limitations in their use mainly due to environmental reasons.

In the recent years, many modifications have been performed on starch as a sizing agents [4,5]. Comparative analyses of different varieties of natural starch, modified starch verses synthetic sizing material have been evaluated. Their effects on mechanical properties like cohesion power, adhesion power, abrasion resistance, bending rigidity have been studied[3]. Among modified starch, starch ester shows better performance [6]. Polyvinyl alcohol (PVA) showed the best properties among all size material since they are easily degraded by biological organisms and it is soluble in water into a crystalline structure polymer solution [7]. PVA is synthesized through saponification process of poly (vinyl acetate)[8] and has long been used by blending with other natural polymers because of its film-forming features [9]. The complete dissolution of PVA in water is bound by its intrinsic properties, which require the water temperature to be at about 100°C with a holding time of 30 min [10].

The common natural sizing agent is maize starch but they have defined problems during weaving and desizing process. These challenges include high amount of warp yarn breakages, high amount of chemical consumption and basicaly poor quality fabrics being produced.To eliminate these challenges, PVA sizing agent will be used and its performance evaluated. In this research, PVA and maize starch sizing agents was compared for their performance on sized yarn and fabric properties. Warp sizing is a significant process

Received: 13.11.2019; Received after Revision: 25.11.2019; Accepted: 26.11.2019; Published: 28.11.2019
©2019 The Authors. Published by G. J. Publications under the CC BY license.

which enormously affects the weaving efficency and characterstics of the woven fabrics.

Materials and experiment

Materials

Cotton yarn of 20Ne was used in this research and it was size using both polyvinyl alcohol (PVA) and maize starch sizing agents. Desizing was done using boiling water for PVA sized yarns and enzymatic desizing agents for starch sized yarns which composed of Amylase, wetting agent, acetic acid, sequestering agent and salt

Experiment

Sizing procedure

Sizing of cotton yarns was done with PVA and maize starch following the recipe shown in Table 1. Water was first added to the mixing tank before the recipe was added. The temperature was raised with steam to 90°C and stirred for 20 min before it was released into the size box.

Table 1. Recipe and Parameters of sizing process

Ingredients	*Setting (maize starch)*	*Setting (poly vinyl alcohol)*
Chemical and starch recipe	55 Kg maize	10Kg PVA only
Water volume	650 litre	650 litre
Cooking temprature	85°c	90°c
Cooking time	25 min	25 min
Viscosity (after cooking)	17	10.7
Final volume(after cooking)	780 l	800 l
Viscosity in size box	17.47	11
Pick-up	4.88	2.5
Article	Sheet 160cm	Sheet 160cm
Count	20Ne (34Nm)	20Ne (34Nm)
Pressure	4 bar	4 bar
Cylinder temprature	110-130°C	110-130°C
Number of thread	3986	3986

Desizing procedure

Before desizing, the maize starch sized fabric was washed with 60°C water and dried. Desizing was done enzymatically with the recipe prepared as shown in Table 2 and pumped into the desizing machine. For the PVA sized fabrics, desizing was done by boiling in water only.

Table 2. Chemical recipes for enzymatic desizing operation

De-sizing chemicals	Amount/preparation, g/l
Amylase	10
Wetting agent	6
Acetic acid	3
Sequestering agent	4
Salt	10

Tests performed

Tensile strength and elongation

The tensile and elongation of the yarns were tested before and after sizing using universal testing machine. The yarns were first conditioned at 65 % RH and 21°C for 24 hr after which 20 samples for each yarn were tested.

Warp yarn breakage

The warp yarn breakage rate was taken from computerized Picanol® air jet loom for both starch sized and PVA sized warp yarns during the weaving process

Test of presence of starch

Iodine test was used to detect the presence of starch before and after desizing. A drop of iodine solution was placed on the fabric. Three possible different colours can be achieved: yellow which indicates the absence of starch, Violate which indicates some presence of starch on the fabric and Brown which indicates the presence starch on the fabric.

Absorbency

Absorbency was done by using a drop of water placed on the fabric and the time it takes to penetrate the fabric was recorded. If the fabric has high absorbance, it will be taken to have a faster wetting time.

Whiteness

Whiteness was measured by the reflectance of the fabric which was done by observation method.

©2019 The Authors. Published by G. J. Publications under the CC BY license.

Results and discussion

Warp yarn breakage, and average weaving efficiency

As seen in the figure 1, ten air jet looms which have the same setting was taken for one shift hour and the amount of warp yarn breakages which is sized with maize starch and PVA recorded and its average warp breakage value was 16 and 10 per hour per machine for maize starch and PVA respectively. As we saw from the Table 3 the breakage rate found on the yarn which is sized by PVA and maize starch would have no significant difference (Table 4 and 6).

As seen from the figure 2 the efficiency of PVA sized yarn was 88% and the efficiency for starch was 85% (Table 5) and there was used 24 picks per centimeter and at 500 Rpm on Picanol ® air jet loom.

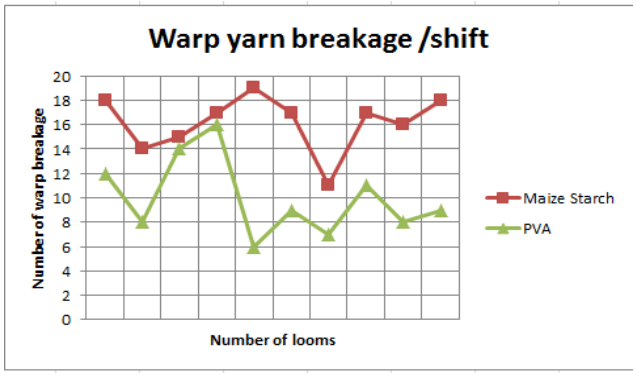

Figure 1. Comparison of warp yarn breakage sized with Maize Starch and PVA

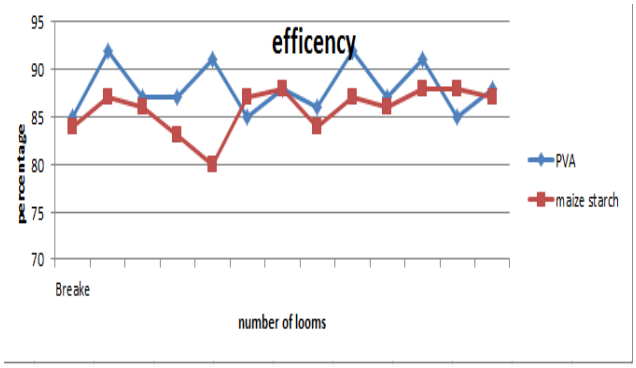

Figure 2. comparsion of efficency for maize starch and PVA

Table 3. Warp yarn breakage for maize starch and PVA sized yarn

Warp yarn breakage rate per 8 hr	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Maize starch	10	15.900	2.28279	0.72188	14.2670	17.5330	11.00	19.00
PVA	10	10.000	3.19722	1.01105	7.7128	12.2872	6.00	16.00
Total	20	12.950	4.05845	0.90750	11.0506	14.8494	6.00	19.00

Table 4. Analysis of variance p-values for Warp yarn breakage sized with Maize starch and PVA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	192.200	1	192.200	24.432	0.000
Within Groups	141.600	18	7.867		
Total	333.800	19			

$$Profit\ for\ one\ machine\ in\ one\ shift\ = (88-85)mt/shift\ = 3mt/shift \quad \text{(iii)}$$

Production of fabric in maize starch and PVA size recipe method respectively

$$Production = \frac{(RPM \times Time \times Efficiency)}{PPC} = 85mt/shift \quad \text{(i)}$$

$$Production = \frac{(RPM \times Time \times Efficiency)}{PPC} = 88mt/shift \quad \text{(ii)}$$

©2019 The Authors. Published by G. J. Publications under the CC BY license.

Table 5: Weaving efficiency of maize starch and PVA sizing agents

Sizing agent	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Maize starch	13	85.000	1.91485	.53109	83.8429	86.1571	80.00	87.00
PVA	13	88.230	2.77350	.76923	86.5548	89.9068	85.00	93.00
Total	26	86.615	2.85765	.56043	85.4612	87.7696	80.00	93.00

Table 6. Analysis of variance p-values for efficiency sized with Maize starch and PVA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	72.570	1	72.570	12.494	0.002
Within Groups	133.590	23	5.808		
Total	206.160	24			

Figure 3 shows the breaking strength value are 17.6,17.3,and 12.1 for PVA,Maize starch and unsized yarn Respectively .As showen in the figure above the warp yarn threated with PVA which showes better in breaking strength than maize starch which ultimately gives enhanced weaving performance.

Figure 4 shows the reaking elongation value are 5.3,5.2,and 7.2 for PVA,Maize starch and unsized yarn Respectively. as showen in the figure above the warp yarn threated with PVA which showes better in elongation than the Maze starch.The yarn which is sized by PVA can resist easily the tension imposed on the yarn during fabric formation.

From Figure 5, Average Values of 45.2% and 42.89 % are an indication of strength regain for the yarn which are sized with PVA and maize starch respectively (Table 7-10). The strength regain which shows the amount of strength which is gained due to sizing material only.

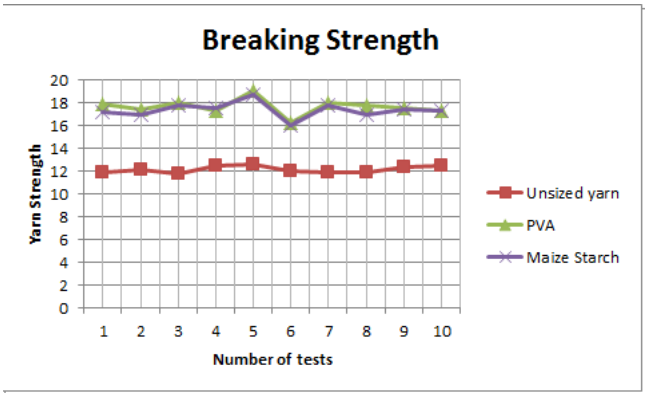

Figure 3. comparsion of yarn strength which sized by PVA and maize starch

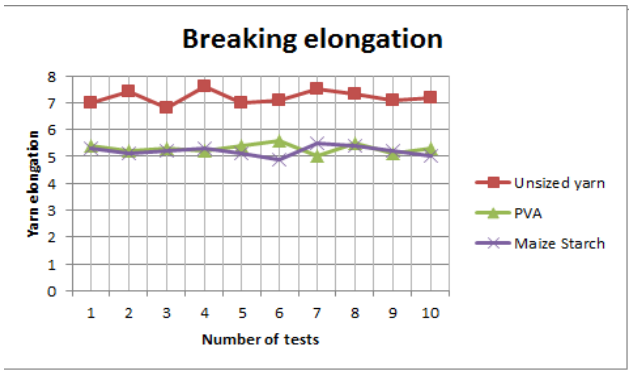

Figure 4. Comparsion of yarn elongation sized by PVA and Maize starch

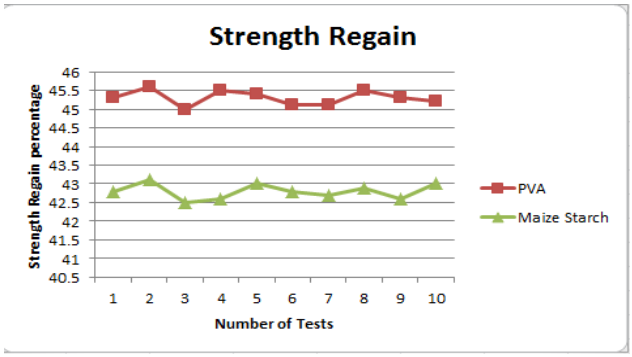

Figure 5. Comparison of strength regain for PVA and maize starch

Table 7. Breaking Strength and elongation of sized warp yarns

Yarn Property	Unsized	Sized	
		PVA	Starch
Breaking Strength (cN/tex)	12.1	17.6	17.3
Breaking Elongation, (%)	7.2	5.3	5.2

©2019 The Authors. Published by G. J. Publications under the CC BY license.

Table 8. Breaking strength unsized, Maize starch and PVA sized yarn

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	12.1000	0.30912	0.09775	11.8789	12.3211	11.70	12.60
2.00	10	17.3000	0.71957	0.22755	16.7853	17.8147	15.90	18.70
3.00	10	17.6000	0.71957	0.22755	17.0853	18.1147	16.20	19.00
Total	30	15.6667	2.63561	0.48119	14.6825	16.6508	11.70	19.00

Table 9. Breaking elongation of unsized, Maize starch and PVA sized yarn

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	7.2000	0.24944	0.07888	7.0216	7.3784	6.80	7.60
2.00	10	5.2000	0.18257	0.05774	5.0694	5.3306	4.90	5.50
3.00	10	5.3000	0.18257	0.05774	5.1694	5.4306	5.00	5.60
Total	30	5.9000	0.95701	0.17472	5.5426	6.2574	4.90	7.60

Table 10. Strength regain Maize starch and PVA sized yarn

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	42.8000	0.20000	0.06325	42.6569	42.9431	42.50	43.10
2.00	10	45.3000	0.20000	0.06325	45.1569	45.4431	45.00	45.60
Total	20	44.0500	1.29716	0.29005	43.4429	44.6571	42.50	45.60

From Figure 6, Average value of 35.84% and 37.10 % are an indication of elongation loss for the yarn which is sized by PVA and maize starch respectively. Which means in case of maize starch the amount of elongation loss is higher than that of PVA since higher elongation loss on sizing machine indicates less force resistance in weaving process

From Figure 7, 2.5 % and 4.88 % are an indication of size regain for the yarn which are sized by PVA and Maize starch (Table 11 and 12). The yarn which are sized by PVA shows lowest size regain that means by using less concentration of size solution it can size more amount of warp ends.

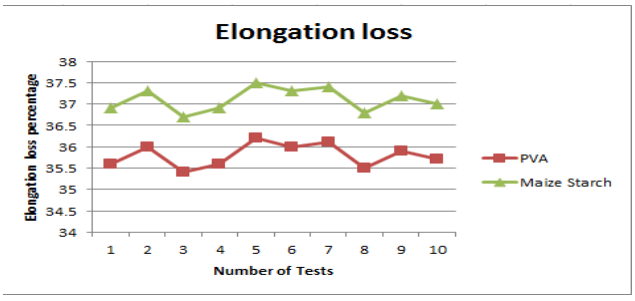

Figure 6. Comparison elongation loss

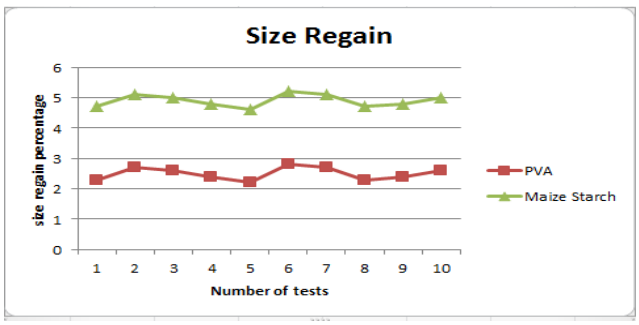

Figure 7. Comparison size regains

Desized fabric properties

As seen in table 12, the starch presence in enzymatic desized fabric and boiled desized fabric is shown. Both fabrics show yellow color which indicates absence of starch. Absorbency was indicated by the time taken by a drop of water to penetrate a fabric where the faster the time, the more absorbent the fabric. From the result, the drop of water penetrated the boiled desized fabric within three minute while for enzymatic desized fabric, the drop of water

©2019 The Authors. Published by G. J. Publications under the CC BY license.

penetrated within five minute. The reflectance of both fabrics showed satisfactorily white as indicated in table 4.

Table 11. Elongation loss Maize starch and PVA sized yarn

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	37.1000	0.27487	0.08692	36.9034	37.2966	36.70	37.50
2.00	10	35.8000	0.27487	0.08692	35.6034	35.9966	35.40	36.20
Total	20	36.4500	0.71855	0.16067	36.1137	36.7863	35.40	37.50

Table 12. Size regain Maize starch and PVA sized yarn

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	4.9000	.20548	0.06498	4.7530	5.0470	4.60	5.20
2.00	10	2.5000	.20548	0.06498	2.3530	2.6470	2.20	2.80
Total	20	3.7000	1.24731	0.27891	3.1162	4.2838	2.20	5.20

Table 13. Comparisons of Enzymatic and Boiling desized fabric

S. No.	Parameters	Enzymatic desized fabric	Boiling desized fabric
1	Starch presence	Yellow	Yellow
2	Absorbancy/Wettability	5 min	3 min
3	Reflectance	White	White

Cost analysis

As seen in table 5, PVA size recipe is prepared four times for every shift and the amount of PVA size required for one preparation was 10 kg while the cost per unit kg was $8.636 therefore the total cost per shift was $345.44 for PVA. As also seen from table 5, starch recipe was also prepared four times per shift and every preparation included 55 kg of starch size. The cost was $1.727 / kg bringing the total cost per shift to be $379.94.

Table 14. Cost of PVA size recipe for one shift

Size recipe	Number of preparation/Shift	For one preparation, kg	Total wt. /shift, kg	Cost in Birr/kg, $/ kg	Total cost, $
PVA	4	10	40	8.636	345.44
Maize Starch	4	55	220	1.727	379.94

Cost analysis for sizing in one shift

Cost of sizing materials used in case of maize starch size agent for one Preparation
= 55Kg × $1.727/Kg = $94.985
But with one shit they prepare four times this means =4× $94.985 = $379.94
Cost of sizing materials used in case of PVA for one preparation =10Kg × $8.636/Kg = $86.36
But with one shit they prepare four times this means = 4×$86.36 = $345.44
Saving per shift if PVA is used = ($379.94 - $345.44) = $34.5 per shift

Desizing recipe

As per table 6, for one preparation, the company was spending the following USD for chemicals in starch recipe;
Total cost = ($ 54.5+$ 14.7+$ 4.5+$ 3.8+$ 4.6) =$ 82.1 were spend for one preparation
Note: Currently during one shift in desizing process to a minimum they prepare a solution four times that means

©2019 The Authors. Published by G. J. Publications under the CC BY license.

In one shift = 4× $ 82.1 = $ 328.4 /shift
Total profit per shift from sizing and desizing process = ($ 34.5+ $ 328.4) = $ 362.9 /shift
For one year = $ 362.9 /shift × 3 shift/day×365day/year= $ 397,375.5/year

Table 15. Cost of desizing chemicals

S. No.	Desize recipe	Amount of chemical for one preparation, g/l	Cost in USD per kg, $	Total cost, $
1	Amylase	10	5.45	54.5
2	Wetting agent	6	2.45	14.7
3	Acetic acid	3	1.5	4.5
4	Sequestering agent	4	0.95	3.8
5	Salt	10	0.46	4.6

Advantage of PVA compared with maize starch size

Improve weavability

The abrasion resistance, elasticity and toughness of yarn sized with polyvinyl alcohol will lead to reductions in warp stop levels. This is particularly true on spun polyester blends where starch does not provide the required protection. Polyvinyl alcohol will also increase the weaving efficiency of 100% cotton fabrics woven on high-speed looms.

Low Add-On

Yarns sized with polyvinyl alcohol can run at lower add-ons because of the adhesion and strength advantage polyvinyl alcohol provides over natural binders. It can be effective at levels as low as one-third that of starch. Operating conditions in each mill will control the degree of starch replacements. Since the lower add on will take up less space on the yarn, it will contribute to improved weavability, particularly on high sley styles. In addition, lower add-ons will lead to several other benefits including more yards on each beam, fewer slasher offs, Less size to remove at desizing and fewer chemicals to process in waste treatment

Lower weave room humidity

The inherent flexibility of films of polyvinyl alcohol resins eliminates the need for high relative humidity in the weave room. Humidity of 65-75% is recommended. Reduction in humidity should be done at a maximum rate of two percentage points every five days to acclimate loom parts and facilitate shed removal via vacuum, resulting in a cleaner weave room. It will provide more comfortable working conditions and length the life of loom parts subject to corrosion.

Conclusions

PVA showed a great advantage in the case of its strength regains, elongation loss and its cost reduction. The result of Poly vinyl alcohol sizing chemical in cotton yarn shows good values of mechanical characterstics than maize starch after leaving in sizing process that is strength regain and hence poly vinyl alcohol sizing material bring beneficial effects on whiteness, easy to desizing and production are concerned. During production of fabric the cost of sizing with PVA is cheaper than sizing with maize starch based on the analysis of cost however in case of poly vinyl alcohol the strength regain much higher this results reduction of breakage which improves the quality of produced fabric more over the consumption of chemicals will decrease on sizing and desizing.

Conflict of interest

The authors declare no conflict of interests.

Acknowledgment

We are thankful to Mr. Mustefa Jemal General Manger and Ato Alehegn Kumelachew Production and Technique Manger, Kombolcha Textile Share Company for giving permission to work in the Industry. We would like also to recognize Dr. Rotich K. Gideon (PhD), Asst. Professor of Textile chemistry, Ethiopian Institute of Textile and Fashion Technology [EiTEX], Bahir dar University for his incessant support of the work.

References

[1] Maatoug S, Evaluation of the weavability of sized cotton warp yarns, Autex Res J 2007;8(4):239-44.
[2] Griffin GJL, Starch polymer blends, Polymer Degradation and Stability 1994;45(2):241-47.
[3] Lata K, Experimental study on application of different sizing agents and its impact of fabric properties, Int J Mult Edu Res 2012;1(4):188-98.

©2019 The Authors. Published by G. J. Publications under the CC BY license.

[4] Chiu CW, Modification of Starch. 3ed. Starch: Chemistry and Technology, Elsevier Inc., 2009.
[5] Maatoug S, Viscoelastic Behaviour of Starch Sized Warps, Journal of Applied Sciences 2007;7(16):2376-79.
[6] Patel PR, Comparative Study of Modified Starch (Esterified) and Conventional Starch (Thin-Boiling) for their Weaving Potential, International Journal of Innovative Research in Science, Engineering and Technology, 2013;2(5):1844-50.
[7] Nair LS, Laurencin CT, Biodegradable polymers as biomaterials, Progress in Polymer Science 2007;32(8):762-98.
[8] Teramoto N, Motoyama T, Yosomiya R, Shibata M, Synthesis, thermal properties, and biodegradability of propyl-etherified starch, European Polymer Journal 2003;39(2):255-61.
[9] Zhang JF, Sun X, Mechanical properties of poly (lactic acid)/starch composites compatibilized by maleic anhydride, Biomacromolecules, 2004;5(4):1446-51.
[10] Pareta R, Edirisinghe MJ, A novel method for the preparation of starch films and coatings, Carbohydrate Polymers 2006;63(3):425-31.

****

©2019 The Authors. Published by G. J. Publications under the CC BY license.