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Ozone Modified Starch and its Application in Yarn Sizing and Advantages

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ABSTRACT

The main objective of the study describes about the process for the modification of the Tapioca starch, Maize starch and Potato starch with Ozone O_3 and its application for yarn sizing. Sizing is the process of applying a protective adhesive coating upon the yarn surface. This is the most important operation to attain maximum weaving efficiency specially for blended & filament yarns. An adhesive material for sizing cotton should have the following characteristics, High degree of polymerization, large number of −OH groups and ease of removal. Due to the large number of hydroxyl group in starch, it is considered as best adhesive sizing material in this study. Starch is usually composed of two components, a straight chain polysaccharide of glucose and a branched chain polysaccharide of glucose. This study demonstrates the three types of natural starch such as Native tapioca starch, maize starch and Potato starch used for the process. Two different process conditions has been discussed that includes simultaneous treatment of ozone and alkali process, stepwise addition of Ozone and alkali process compared to without ozone and alkali treatment. After the treatment process, analysis of viscosity, abrasion resistance and tensile strength are the most important factor to be considered in yarn sizing. From the result analysis, Tapioca starch with stepwise addition of Ozone and alkali has the low viscosity of 182 cps than maize and potato starch. Tapioca starch has the higher abrasive resistance of 2200 CN/cm^2 than maize and potato starch. Tensile strength test resulted that

decreasing weft count, increases fabric assistance as the pick density increases. Stepwise process of tapioca starch contains higher tensile strength than Maize and potato starch. Tapioca starch with stepwise addition of Ozone and alkali of single yarn strength was 8.89 N, when the pick density increases, fabric assistance of single yarn strength increased to 8.95 N. Among the three types of modified starch, Tapioca starch has the highly potent sizing material provides high strength, efficient desizing, improved adhesion and high abrasion resistance with reduced cost for yarn sizing.

Keywords: Tapioca starch, Maize starch, Potato starch, Yarn Sizing, Viscosity, Abrasion resistance, Universal strength

1. INTRODUCTION

Sizing is a technological process of wet processing of warp yarns to obtain additional properties which are necessary for weaving. This is the most important operation to attain maximum weaving efficiency specially for blended & filament yarns **(Maatoug S et al., 2007).** Sizing efficacy does not depend only on the adhesion between the applied sizing agent and the yarn, but also on the ability to form a film, on rheological properties of the size, physical-chemical yarn properties, as well as on the technological parameters in the sizing process **(Stegmaier T et al, 2008).** Furthermore, it is necessary to completely remove the sizing agent from the fabric after the weaving process in an environmentally friendly manner. The sizing process is nowadays more aimed towards the development and use of natural-based sizing agents. Sizing agents used nowadays can be divided into the following groups: starches, carboxymethylcellulose, polyvinyl alcohols, polyacrylates and polyester resins **(Sandhu K S et al, 2008) (Hebeish A et al., 2008).** With the advent of synthetic fibers such as polyester and nylon, the use of high-speed shuttle less weaving technology, higher performance is required for sizing the fabric. Polyvinyl alcohol (PVOH) is a preferred ingredient in size compositions because of its excellent adhesion to synthetic fibers but PVOH has some disadvantages, such as high cost and the high dry-breaking strength of the warp. The high dry-breaking strength causes difficulties for the warp to split at the breaker bars of the slasher **(Down J, 1999).**

Currently, hydroxylated starches are extensively used for textile sizing. Starch is treated with propylene oxide to produce hydroxylated starch. However, propylene oxide is classified as carcinogen (Category 2) and can cause cancer. Stringent risk control measures to reduce exposure to low level (ppm) of propylene oxide are being evaluated by environmental agencies. In the past, acid and enzyme thinned and hydroxylated starches have been the preferred ingredients in starch formulations for cotton warps and weaving on shuttle looms. This is due to the low costs and capability of these types of starches to enhance yarn sizing. The acid and enzyme thinned starch have been used with PVOH to reduce sizing cost and the high dry breaking strength of PVOH-sized warps. The acid-thinned starch is not compatible with PVOH, which causes a decrease in the adhesion of size to the warp and consequently a decline in the quality of the sized warp and weaving efficiency **(Down J, 1999).**

An adhesive material for sizing cotton should have the following characteristics, High degree of polymerization, large number of −OH groups and ease of removal. Due to the large number of hydroxyl group in starch, it is considered as best adhesive sizing material. Starch properties depend on the relationship between amylose and amylopectin, but also on other constituents found in a starch granule, such as phosphates, lipids, phospholipids, etc. The complexity of the sizing process is reflected in a number of parameters related to the properties of sizing agents, used yarns and sizing and weaving machines which is always a challenge and is a significant field of research. However, amylopectin, as the main starch ingredient, exerts a dominant influence on starch properties **(Sandhu K S et al, 2008) (Hebeish A et al., 2008).** Starch is mostly commercially applied in sizing cotton warp yarns, although with considerable shortcomings: (a) molecule size which limits the penetration into the yarn, (b) instability of size viscosity due to temperature changes during cooking until preparation and sizing process, (c) film rigidity (in particular in the absence of a high-quality lubricant), (d) sensitivity to microorganisms (decay, degradation) **(Kova cevic S and Penava Z, 2004).** Modification of natural starches is done just to eliminate the above mentioned shortcomings and to increase their usability for industrial applications **(Ashdown S P, 2007).**

In this present study, to overcome the disadvantages of acid and enzymes thinned starch, modified tapioca starch maize starch and potato were treated with ozone under alkaline condition and its use in sizing. The sizing formulation of the present invention is better than other known size formulations because it has high PVOH compatibility and possesses other characteristics such as strength and flexibility on the yarn, adhesion to the yarn, resistance to abrasion, control of penetration into and encasement of the yarn, and viscosity stability, which is essential for a high-performance textile sizing agent. Modified starch can be easily de-sized by alfa-amylase enzymes without involving detergents. In contrast, the modified starch has advantage over PVA (poly-vinyl alcohol) based sizing agents cannot be de-sized and discharged directly, since PVA is hazardous to the eco-system. In addition, viscosity is very important for highly efficient sizing.

2. MATERIALS & METHODS

2.1 Sample collection

Tapioca starch, Maize starch and Potato starch were collected from the local market.

2.2 Modification of Starch using alkali and ozone treatment

This study relates to modified starch, a process for its preparation and its use in yarn sizing. The new starch derivative of the present method can be used in conjunction with very less polyvinyl alcohol as a size composition. The sizing formulation of the present study is better than other known size formulations because it has high PVOH compatibility and possesses other characteristics such as strength and flexibility on the yarn, adhesion to the yarn, resistance to abrasion, control of penetration into and encasement of the yarn, and viscosity stability, which is essential for a high-

performance textile sizing agent. Modified starch can be easily de-sized by alfa-amylase enzymes without involving detergents. The following are the process for the modification of Tapioca starch, Maize starch and Potato starch.

2.2.1 Tapioca starch with simultaneous treatment of ozone and alkali

One kg of Tapioca starch was suspended in 1000 ml water to provide a suspension of 50% solids. The flask containing this suspension was equipped with an impeller to keep the starch in suspension and to avoid agglomeration. The suspension was heated to 46 °C and maintained at this temperature. The pH was adjusted to 8.0 by using 10% NaOH or KOH and immediately 2 mL of ozone (OZONETEK) was added and the mixture was stirred for 24 to 36 hrs under 200 rpm agitation. Further the starch is separated by filtration and the treated starch is water washed and dried at 60^0 c for 4 to 6 hrs to obtain nearly 970 g.

2.2.2 Tapioca starch with sstepwise treatment of ozone and alkali

One kg of Tapioca starch was suspended in 1000 ml water to provide a suspension of 50% solids. The flask containing this suspension was equipped with an impeller to keep the starch in suspension and to avoid agglomeration. The suspension was heated to 46 °C and maintained at this temperature. The initial pH was measured 7.0 and two milliliters of ozone (OZONETEK) added and the reaction was allowed to proceed for 4 to 6 hrs for starch thinning and further the pH is adjusted with sodium or potassium hydroxide to 8 and reacted for 24 to 36 hrs under 200 rpm agitation. Further the starch is separated by filtration and the treated starch is water washed and dried at 60 deg c for 4 to 6 hrs to obtain nearly 950 g.

2.2.3 Maize starch with simultaneous treatment of ozone and alkali

One kg of Maize starch was suspended in 1000 ml water to provide a suspension of 50% solids. The flask containing this suspension was equipped with an impeller to keep the starch in suspension and to avoid agglomeration. The suspension was heated to 46 °C and maintained at this temperature. The pH was adjusted to 8.0 by using 10% NaOH or KOH and immediately 2 mL of ozone (OZONETEK) was added and the mixture was stirred for 24 to 36 hrs under 200 rpm agitation. Further the starch is separated by filtration and the treated starch is water washed and dried at 60 deg c for 4 to 6 hrs to obtain nearly 965 g.

2.2.4 Maize starch with stepwise treatment of ozone and alkali

One kg of Maize starch was suspended in 1000 ml water to provide a suspension of 50% solids. The flask containing this suspension was equipped with an impeller to keep the starch in suspension and to avoid agglomeration. The suspension was heated to 46 °C and maintained constant at this temperature. The initial pH was measured 7.0 and two milliliters of ozone (OZONETEK) added and the reaction was allowed to proceed for 4 to 6 hrs for starch thinning and further the pH is adjusted with sodium or potassium hydroxide to 8 and reacted for 24 to 36 hrs under 200 rpm agitation. Further the starch is separated by filtration and the treated starch is water washed and dried at 60 deg c for 4 to 6 hrs to obtain nearly 905 g.

2.2.5 Potato starch with simultaneous treatment of ozone and alkali

One kg of Potato starch was suspended in 1000 ml water to provide a suspension of 50% solids. The flask containing this suspension was equipped with an impeller to keep the starch in suspension and to avoid agglomeration. The suspension was heated to 46 °C and maintained at this temperature. The pH was adjusted to 8.0 by using 10% NaOH or KOH and immediately 2 mL of ozone (OZONETEK) was added and the mixture was stirred for 24 to 36 hrs under 200 rpm agitation. Further the starch is separated by filtration and the treated starch is water washed and dried at 60 deg c for 4 to 6 hrs to obtain nearly 950 g.

2.2.6 Potato starch with stepwise treatment of ozone and alkali

One kg of Potato starch was suspended in 1000 ml water to provide a suspension of 50% solids. The flask containing this suspension was equipped with an impeller to keep the starch in suspension and to avoid agglomeration. The suspension was heated to 46 °C and maintained constant at this temperature. The initial pH was measured 7.0 and two milliliters of ozone (OZONETEK) added and the reaction was allowed to proceed for 4 to 6 hrs for starch thinning and further the pH is adjusted with sodium or potassium hydroxide to 8 and reacted for 24 to 36 hrs under 200 rpm agitation. Further the starch is separated by filtration and the treated starch is water washed and dried at 60 deg c for 4 to 6 hrs to obtain nearly 890 g.

2.2 Viscosity (Nattapulwat N *et al.,* 2009)

The flow viscosity of native starch and modified starch from each example in centipoises, of the 5% starch paste contained in the 300 ml beaker was determined using a Brookfield Viscometer DV -II+Pro by using Spindle RV4 100 RPM. The Brookfield is run up and down the scale twice with the second set of readings used. The yarn sizing process is essential in reducing the molecular weight of starch and viscosity reduction and consequently improving the efficiency of binding to the matrix to facilitate weaving. Modified starch derived from examples are prepared with 10 % w/v continuous stirring at temperature 75 °C to allow gelatinization to the viscosity tabulated in table 1 and coated on the thread of 20’s size and dried.

2.3 Abrasion resistance

The sizing effect is of decisive importance for the weaving properties of a warp yarn. This effect is closely connected with the abrasion resistance of the sized yarn. The abrasion resistance of the yarn was measured with the Zweigle abrasion tester (G552 abrasion tester, Zweig Textile GmbH&Co.KG, Germany) (**Wei Q *et al.*, 2009)**.Twenty; weighted threads (cotton staple yarn English count Ne12) are laid over the shaft and abraded at the same speed and under the same pressure until they break. To ensure that fibrous deposits in the abrasive do not affect the abrasive action, the shaft is advanced after each stroke. The number of abrasive strokes withstands before breaking is read off from a counter, and the average figure calculated. The higher the abrasion number obtained, the higher the abrasion resistance of the yarn at working pressure on test specimen 2.5 cN/cm2 and rotational speed 47.5+/- 2.5 rpm.

2.4 Tensile Strength (Haque M, 2009)

Both the warp and weft yarns were tested to determine the tensile strength. The instrument used for the test was Titan Universal Strength Tester. The jaws for yarn testing were set and the maximum air pressure maintained in the compressor was 7 Bar. After opening the titan software in the computer the yarn testing standard was set to ASTM D2256 (sample length 250 mm and time of extension 20 seconds) and the other required parameters (pretension, break detection, rate of extension, no. of specimen) were set. Then the test was started after mounting the yarn sample between the jaws. Strength is one of the most important parts of parameter of woven fabric. Strength is directly related to the useful life of a garment/and textile article. Both warp and weft way strength of the fabric was investigated by using Titan Universal Strength Tester available in the AUST textile testing lab. The specimen size was (Length X Width = 14 X 7.62 cm). The test results are shown in the Table 3.

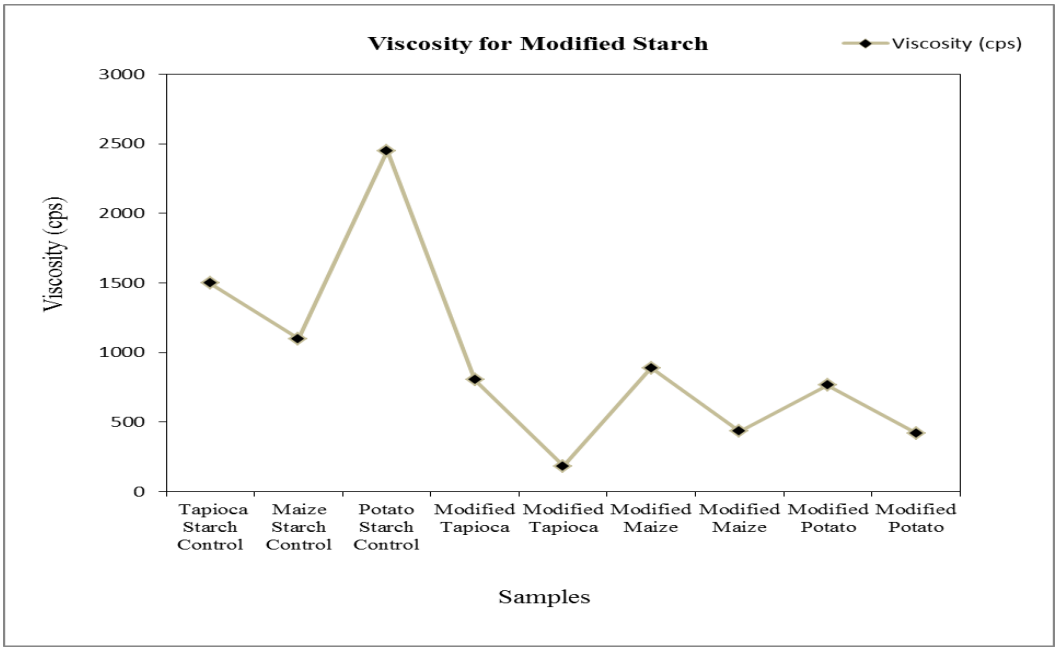
3. RESULTS & DISCUSSION

3.1 Viscosity

The viscosity value is important in size application, as it has a considerable effect on the amount of liquor pickup. Saving of the drying energy associated with surface sizing can be made by increasing the solids content of the starch solution in size press. Therefore, it is highly desirable to develop low viscosity starches for surface sizing. Viscosity was analyzed for three types of modified starch compared with control shown in the Table 1. From the result analysis, Tapioca starch with stepwise addition of ozone and alkali has the low viscosity of 182 cps than maize and potato starch shown in Graph 1.

Table 1: Brookfield Viscosity of 5% cooked solution at 50 deg C

S.No	Details	Viscosity (cps)
1	Native Tapioca Starch Control	1500
2	Maize Starch Control	1100
3	Potato Starch Control	2450
4	Modified Tapioca	804
5	Modified Tapioca	182
6	Modified Maize	888
7	Modified Maize	434
8	Modified Potato	765
9	Modified Potato	421



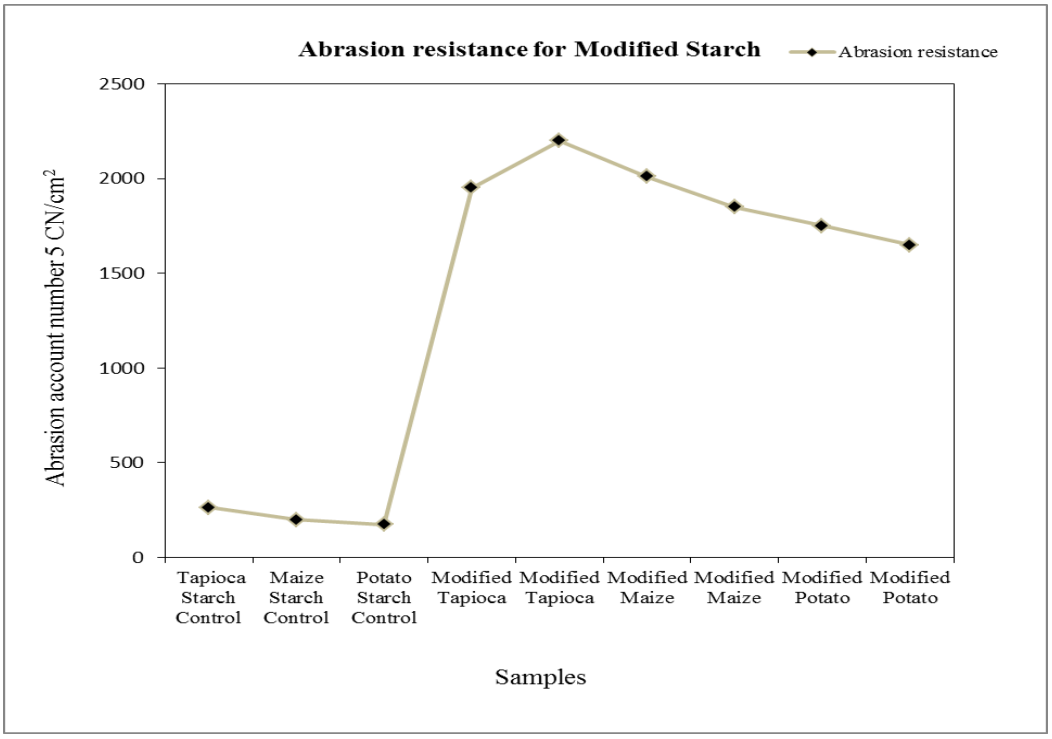
Graph 1: Brookfield Viscosity of 5% cooked solution at 50 deg C

3.2 Abrasion resistance

Abrasion is wearing a way of any part of material by rubbing against another surface. Higher the abrasion account value gives the higher abrasion resistance. Abrasion test was analyzed for three types of modified starch compared with control shown in the Table 2. From the result analysis, Tapioca starch with stepwise addition of ozone and alkali has the higher abrasion account value of 2200 CN/cm^2 gives the higher abrasion resistance shown in Graph 2.

Table 2: Abrasion tested (G552 abrasion tester)

S.No	Details of the samples	Abrasion account number 5 CN/cm^2
1	Native Tapioca Starch Control	265
2	Maize Starch Control	200
3	Potato Starch Control	175
4	Modified Tapioca	1950
5	Modified Tapioca	2200
6	Modified Maize	2010
7	Modified Maize	1850
8	Modified Potato	1750
9	Modified Potato	1650



Graph 2: Abrasion tested (G552 abrasion tester)

3.4 Tensile strength Test

Both the warp and weft yarns were tested to determine the tensile strength. Single weft yarn strength was calculated using two different ways. It was observed (Table 3) that single yarn strength calculated from the fabric strength is always greater than that of the single yarn strength. This is because the strength of the yarn while in the fabric is assisted by some other factors like the cohesive forces of the adjacent yarns and the force due to the interlacement of yarns. This additional yarn strength is regarded as "fabric assistance". It can be seen in the Table 3 that the fabric assistance increases as the pick density increases. Strength was analyzed for three types of modified starch compared with control shown in the Table 2. From the result analysis, Tapioca starch with stepwise addition of Ozone and alkali of single yarn strength was 8.89 N, when the pick density increases, fabric assistance of single yarn strength increased to 8.95 N. According to the finding of Table 3 shows that we can generate a relatively stronger fabric by increasing threads/inch. The strength of very lighter fabrics can also be increased by increasing the threads/inch.

Table 3: Effect of Fabric assistance on individual weft yarn Strength
[Force required to break the specimen (N)]

S.No	Weft count (Ne)	Single yarn Strength (N)	No. Pick wheel teeth = 42	No. Pick wheel teeth = 52	No. Pick wheel teeth = 66
	Control Tapioca				
1	28.5	2.7625	2.4565	2.635	2.6435
2	20	2.38	2.754	2.8305	2.9155
3	10	7.5565	7.548	7.5735	7.6075
	Control Maize				
4	28.5	2.925	2.601	2.79	2.799
5	20	2.52	2.916	2.997	3.087
6	10	8.001	7.992	8.019	8.055
	Control Potato				
7	28.5	2.275	2.023	2.17	2.177
8	20	1.96	2.268	2.331	2.401
9	10	5.9563	5.9496	5.9697	5.9965
	Modified Tapioca				
10	28.5	3.25	2.89	3.1	3.11
11	20	2.8	3.24	3.33	3.43
12	10	8.765	8.755	8.785	8.825
	Modified Tapioca				
13	28.5	3	2.64	2.85	2.86
14	20	3.05	3.49	3.58	3.68
15	10	8.89	8.88	8.91	8.95
	Modified Maize				
16	28.5	3.025	2.701	2.89	2.899
17	20	2.64	3.036	3.117	3.207
18	10	8.151	8.142	8.169	8.205
	Modified Maize				
19	28.5	2.77	2.52	2.78	2.88
20	20	2.5	3.04	3.13	3.07
21	10	7.7	8.4	8.69	8.79
	Modified Potato				
22	28.5	2.4	2.148	2.295	2.302
23	20	2.081	2.389	2.452	2.522
24	10	6.0773	6.0706	6.0907	6.1175
	Modified Potato				
25	28.5	2.2	1.948	2.095	2.102
26	20	1.981	2.289	2.352	2.422
27	10	5.6273	5.6206	5.6407	5.6675

4. ADVANTAGES OF MODIFIED TAPIOCA STARCH IN YARN SIZING

1. Eco-friendly starch modification process and product.
2. Provides higher affinity to yarn.
3. Increased performance of yarn sizing than propylene oxide which is a carcinogen.
4. Reduced use of PVOH additives in sizing compositions.
5. Reduces sizing cost

CONCLUSION

Modification of tapioca, maize and potato starch was processed using ozone and alkali. After the treatment process, analysis of viscosity, abrasion resistance and tensile strength are the most important factor to be considered in yarn sizing. From the result analysis, Tapioca starch with stepwise addition of Ozone and alkali has the low viscosity of 182 cps than maize and potato starch. Tapioca starch with stepwise addition of Ozone and alkali has the higher abrasive resistance of 2200 CN/cm^2 than maize and potato starch. Tensile strength test resulted that decreasing weft count, increases fabric assistance as the pick density increases. Among the three types of modified starch, Tapioca starch with stepwise addition of Ozone and alkali treatment is higher tensile strength than Maize and potato starch. Tapioca starch with stepwise addition of Ozone and alkali of single yarn strength was 8.89 N, when the pick density increases, fabric assistance of single yarn strength increased to 8.95 N. It was to conclude that among the three types of modified starch, Tapioca starch is the highly potent sizing material used for yarn sizing with reduced sizing cost. This is an eco-friendly process and do not emits environmentally toxic residues. The modified starch provides high strength, efficient desizing, improved adhesion and high abrasion resistance to yarn sizing using a high powered weaving loom. All of these contribute for better sizing and high fabric quality.

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