An Investigation on the Benefits and Uses of Ozone-Modified Starch in Yarn Sizing

***Dr. Seema Arora**

ABSTRACT

The study's primary goal outlines the procedure for modifying tapioca, maize, and potato starches using ozone and how it may be used to adjust yarn size. Applying a protective adhesive covering to the yarn's surface is known as sizing. This is the most crucial step in achieving optimal weaving efficiency, particularly for filament and mixed yarns. The qualities listed below are ideal for an adhesive used to size cotton: significant amount of -OH groups, high degree of polymerization, and ease of removal. In this research, starch is regarded as the best adhesive sizing material because of its high hydroxyl group count. Two components typically make up starch: a glucose polymer with a straight chain and another with a branch chain. This research shows the three forms of natural starch that are employed in the process: potato starch, maize starch, and native tapioca starch. In contrast to the absence of ozone and alkali treatment, two distinct process conditions have been discussed: stepwise addition of ozone and alkali process and simultaneous treatment of ozone and alkali process. The most crucial factors to take into account while sizing yarns after treatment are viscosity, abrasion resistance, and tensile strength. According to the study of the results, tapioca starch with ozone and alkali added gradually has a lower viscosity (182 cps) than potato and maize starch. Compared to maize and potato starch, tapioca starch has a greater abrasion resistance of 2200 CN/cm2. According to the results of a tensile strength test, as pick density rises, fabric assistance increases as weft count decreases. Compared to maize and potato starch, tapioca starch produced step-by-step has a greater tensile strength. The single yarn strength of tapioca starch with ozone and alkali added gradually was 8.89 N; when the pick density rose, the fabric assistance of the single yarn strength rose to 8.95 N. Tapioca starch is the most effective sizing material among the three forms of modified starch; it offers high strength, effective desizing, enhanced adhesion, and excellent abrasion resistance at a lower cost for yarn size.

Keywords: Viscosity, Abrasion Resistance, Universal Strength, Yarn Size, Tapioca, Maize, Potato Starches

1. INTRODUCTION

Sizing is a technical procedure that involves wet treating warp yarns to provide them extra qualities needed for weaving. According to Maatoug S et al. (2007), this is the most crucial step in achieving optimal weaving efficiency, particularly for mixed and filament yarns. The ability to form a film, the size's rheological characteristics, the physical-chemical characteristics of the yarn, and the technological parameters used in the sizing process are all factors that affect how effective sizing is (Stegmaier T et al, 2008).

Additionally, the sizing agent must be entirely removed from the cloth in an eco-friendly way after the weaving process. These days, the discovery and use of natural-based sizing agents are the main goals of the size procedure. Starches, carboxymethylcellulose, polyvinyl alcohols, polyacrylates, and polyester resins are the classes of sizing agents that are employed nowadays (Sandhu K S et al, 2008) (Hebeish A et al., 2008). Higher performance is needed for fabric sizing due to the introduction of synthetic fibers like polyester and nylon, as well as the usage of high-speed shuttle less weaving technology. Due of its superior adherence to synthetic fibers, polyvinyl alcohol (PVOH) is a favored element in size formulations; nevertheless, PVOH has several drawbacks, including high warp dry-breaking strength and high cost. The warp finds it difficult to split at the slasher's breaker bars because of the strong dry-breaking strength (Down J, 1999).

Nowadays, textile scaling makes substantial use of hydroxylated starches. Propylene oxide is applied to starch to create hydroxylated starch. Propylene oxide, however, is categorized as a carcinogen (Category 2) and has the potential to cause cancer. Environmental authorities are assessing strict risk management strategies to lower exposure to low levels (ppm) of propylene oxide. The favored constituents in starch formulations for cotton warps and shuttle loom weaving in the past have been hydroxylated and acid and enzyme thinned starches. This is because these starches may improve yarn size and are reasonably priced. PVOH-sized warps offer a high dry breaking strength and a lower sizing cost because to the usage of acid and enzyme-thinned starch. Due to the acid-thinned starch's incompatibility with PVOH, size adherence to the warp decreases, resulting in a reduction in the sized warp's quality and weaving efficiency (Down J, 1999).

The following qualities are essential for an adhesive used to size cotton: high degree of polymerization, plenty of -OH groups, and removal simplicity. Starch has a lot of hydroxyl groups, which makes it the greatest material for adhesive sizing. In addition to other components present in a starch granule, such as phosphates, lipids, phospholipids, etc., the connection between amylose and amylopectin determines the qualities of starch. Numerous factors pertaining to the characteristics of size agents, yarns, and sizing and weaving machinery indicate the intricacy of the sizing process, which is a major area of study and a constant challenge. But being the primary component of starch, amylopectin has a significant impact on its characteristics (Sandhu K S et al, 2008). (Hebeish A. and others, 2008). Although it has several drawbacks, starch is primarily used commercially to size cotton warp yarns. These include: (a) molecule size, which restricts penetration into the yarn; (b) temperature changes during cooking until preparation and sizing process, which causes instability of size viscosity; (c) film rigidity, especially when a high-quality lubricant is not used; and (d) sensitivity to microorganisms (decay, degradation) (Kova cevic S and Penava Z, 2004). Natural starches are modified only to improve their suitability for industrial uses and to get rid of the aforementioned drawbacks (Ashdown S P, 2007).

In this work, modified tapioca starch, maize starch, and potato were treated with ozone in an alkaline environment and used for sizing in order to overcome the drawbacks of acid and enzymes that thinned starch. Because of its high PVOH compatibility and other qualities like strength and flexibility on the yarn, adhesion to the yarn, resistance to abrasion, control over penetration into and encasement of the yarn, and viscosity stability—all crucial for a high-performance textile sizing agent—the sizing formulation of the current invention is superior to other known size formulations. Alfaamylase enzymes readily break down modified starch without the need for detergents. The modified starch, on the other hand, has an advantage over sizing agents based on poly-vinyl alcohol (PVA), which are harmful to the environment and cannot be de-sized and released directly. Furthermore, viscosity is crucial for very effective sizing.

2. MATERIALS & METHODS

2.1 Sample collection

We gathered tapioca, maize, and potato starches from the neighborhood market.

2.2 Alkali and ozone therapy for starch modification

The manufacture of modified starch and its use in yarn sizing are the subjects of this work. As a size composition, the novel starch derivative from the current process may be combined with relatively little polyvinyl alcohol. Because of its high PVOH compatibility and other qualities like strength and flexibility on the yarn, adhesion to the yarn, resistance to abrasion, control over penetration into and encasement of the yarn, and viscosity stability—all crucial for a high-performance textile sizing agent—the sizing formulation used in this study is superior to other known size formulations. Alfaamylase enzymes readily break down modified starch without the need for detergents. The steps involved in modifying tapioca, maize, and potato starches are following.

2.2.1 Tapioca starch treated with alkali and ozone at the same time

To create a 50% solids suspension, one kilogram of tapioca starch was dissolved in 1000 milliliters of water. To prevent agglomeration and maintain the starch in suspension, the flask holding this suspension included an impeller. The temperature of the suspension was raised to 46 °C and kept there. After adjusting the pH to 8.0 with 10% NaOH or KOH, 2 mL of ozone (OZONETEK) was added right away, and the mixture was agitated at 200 rpm for 24 to 36 hours. In order to produce roughly 970 g, the starch is further separated by filtering, water washed, and dried at 600 c for 4 to 6 hours.

2.2.2 Tapioca starch treated gradually with alkali and ozone

To create a 50% solids suspension, one kilogram of tapioca starch was dissolved in 1000 milliliters of water. To prevent agglomeration and maintain the starch in suspension, the flask holding this suspension included an impeller. The temperature of the suspension was raised to 46 °C and kept there. After measuring the initial pH at 7.0, two milliliters of ozone (OZONETEK) were added, and the reaction was let to run for four to six hours in order to thin the starch. The pH was then corrected to 8 using sodium or potassium hydroxide, and it was agitated for twenty-four to thirty-six hours at 200 rpm. To get close to 950 g, the starch is further separated by filtration, water washed, and dried at 60 degrees Celsius for four to six hours.

2.2.3 Maize starch treated with alkali and ozone at the same time

To create a 50% solids suspension, one kilogram of maize starch was dissolved in 1000 milliliters of water. To prevent agglomeration and maintain the starch in suspension, the flask holding this suspension included an impeller. The temperature of the suspension was raised to 46 °C and kept there. After adjusting the pH to 8.0 with 10% NaOH or KOH, 2 mL of ozone (OZONETEK) was added right away, and the mixture was agitated at 200 rpm for 24 to 36 hours. In order to get roughly 965 g, the starch is further separated by filtering, water washed, and dried at 60 degrees Celsius for four to six hours.

2.2.4 Maize starch treated gradually with alkali and ozone

To create a 50% solids suspension, one kilogram of maize starch was dissolved in 1000 milliliters of water. To prevent agglomeration and maintain the starch in suspension, the flask holding this suspension included an impeller. The temperature of the suspension was raised to 46 °C and kept there. After measuring the initial pH at 7.0, two milliliters of ozone (OZONETEK) were added, and the reaction was let to run for four to six hours in order to thin the starch. The pH was then raised to 8 using sodium or potassium hydroxide, and it reacted for twenty-four to thirty-six hours while being stirred at 200 rpm.

In order to get about 905 g, the starch is further separated by filtering, water washed, and dried at 60 degrees Celsius for four to six hours.

2.2.5 Potato starch treated with alkali and ozone at the same time

To create a 50% solids suspension, one kilogram of potato starch was dissolved in 1000 milliliters of water. An impeller was installed in the flask holding this suspension in order to

prevent agglomeration and maintain the starch in suspension. The temperature of the suspension was raised to 46 °C and kept there. After adjusting the pH to 8.0 with 10% NaOH or KOH, 2 mL of ozone (OZONETEK) was added right away, and the mixture was agitated at 200 rpm for 24 to 36 hours. In order to produce roughly 950 g, the starch is further separated by filtering, water washed, and dried at 60 degrees Celsius for four to six hours.

2.2.6 Potato starch treated gradually with alkali and ozone

To create a 50% solids suspension, one kilogram of potato starch was dissolved in 1000 milliliters of water. To prevent agglomeration and maintain the starch in suspension, the flask holding this suspension included an impeller. The temperature of the suspension was raised to 46 °C and kept there. After measuring the initial pH at 7.0, two milliliters of ozone (OZONETEK) were added, and the reaction was let to run for four to six hours in order to thin the starch. The pH was then raised to 8 using sodium or potassium hydroxide, and it reacted for twenty-four to thirty-six hours while being stirred at 200 rpm.

In order to achieve around 890 g, the starch is further separated by filtering, water washed, and dried at 60 degrees Celsius for four to six hours.(Nattapulwat N et al., 2009) 2.2 Viscosity

Using a Brookfield Viscometer DV-II+Pro and Spindle RV4 100 RPM, the flow viscosity of the 5% starch paste in the 300 ml beaker was measured in centipoises for both native and modified starch from each sample. Using the second set of measurements, the Brookfield is run twice up and down the scale.

The process of yarn size is crucial for lowering the viscosity and molecular weight of starch, which enhances binding to the matrix and makes weaving easier. To enable gelatinization to the viscosity listed in Table 1, modified starch generated from examples is made with 10% w/v continuous stirring at 75 °C. It is then coated on threads of 20's size and allowed to dry.

2.3 Abrasion resistance

The size effect has a significant impact on a warp yarn's weaving characteristics. The abrasion resistance of the sized yarn is strongly related to this effect. The Zweigle abrasion tester (G552 abrasion tester, Zweig Textile GmbH&Co.KG, Germany) was used to assess the yarn's abrasion resistance (Wei Q et al., 2009).Twenty weighted threads (English count Ne12 cotton staple yarn) are placed over the shaft and abraded until they break at the same rate and pressure.

The shaft is advanced after each stroke to guarantee that fibrous deposits in the abrasive do not impair the abrasive action. A counter is used to determine how many abrasive strokes the material can tolerate before breaking, and the average is then computed. The abrasion resistance of the yarn at working pressure on test specimen 2.5 cN/cm2 and rotating speed 47.5+/- 2.5 rpm increases with the abrasion number obtained.

2.4 Strength in Tensile (Haque M, 2009)

Tensile strength tests were performed on both the warp and weft yarns. Titan Universal Strength Tester was the tool used for the test. The compressor's maximum air pressure was kept at 7 Bar, and the jaws for testing yarn were adjusted. The computer's Titan program was launched, and the yarn testing standard (ASTM D2256; sample length: 250 mm; extension time: 20 seconds) and other necessary settings (pretension, break detection, extension rate, and number of specimens) were configured. After installing the yarn sample between the jaws, the test was started. One of the most crucial aspects of woven cloth is its strength.

The usable life of a garment or textile item is closely correlated with its strength. The Titan Universal Strength Tester, which is accessible at the AUST textile testing facility, was used to examine the fabric's warp and weft way strengths. The dimensions of the specimen were 14 x 7.62 cm (length x width). Table 3 displays the test results.

3. RESULTS & DISCUSSION

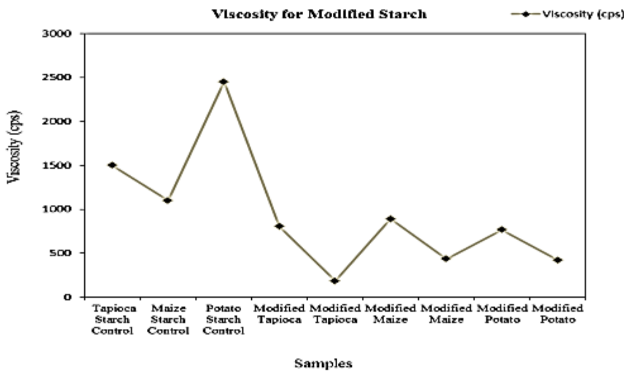
3.1 Viscosity

As it significantly affects the quantity of liquor pickup, the viscosity value is crucial in size application. By adding more solids to the starch solution in the size press, the drying energy needed for surface sizing may be reduced. For surface scaling, it is thus very desirable to create low viscosity starches.

Viscosity was measured for the three modified starch kinds and compared to the control, as shown in Table 1. According to the examination of the results, tapioca starch with ozone and alkali added gradually has a lower viscosity (182 cps) than the starches from maize and potatoes, as 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



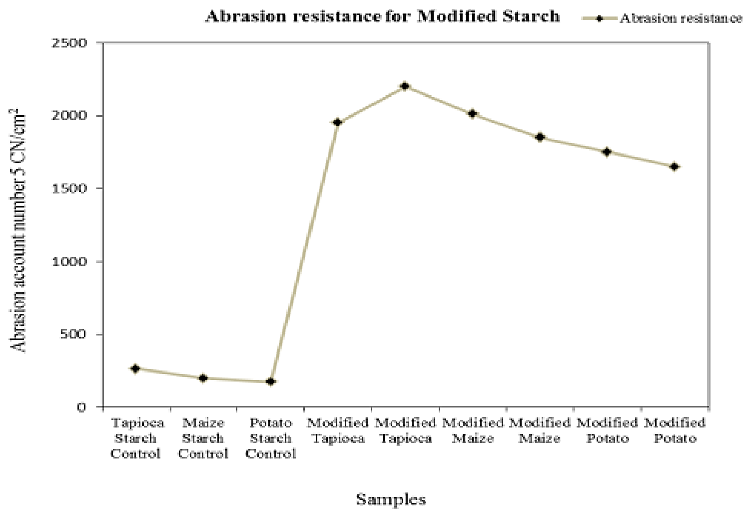
Graph 1: Brookfield Viscosity of 5% cooked solution at 50 deg C

3.2 Resistance to abrasion

Any area of material that is worn by rubbing against another surface is called an abrasion. Three different forms of modified starch were subjected to an abrasion test, which was compared to the control in Table 2. According to the analysis of the results, tapioca starch with ozone and alkali added gradually has a higher abrasion account value of 2200 CN/cm2, which results in a greater abrasion resistance, as 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



3.4 Tensile strength Test

Tensile strength tests were performed on both the warp and weft yarns. Two methods were used to calculate the strength of a single weft yarn. Table 3 shows that the single yarn strength determined from the fabric strength is consistently higher than the single yarn strength. This is because other elements, such as the cohesive forces of nearby yarns and the force resulting from yarn interlacing, help to increase the yarn's strength while it is in the fabric. "Fabric assistance" is the term used to describe this extra yarn strength. As the pick density rises, Table 3 shows that the fabric help also increases. Three different forms of modified starch were evaluated for strength in comparison to the control, which is shown in Table 2. According to the analysis of the results, the strength of the single yarn made from tapioca starch with a stepwise addition of ozone and alkali was 8.89 N; as the pick density grew, the strength of the fabric assistance of the single yarn climbed to 8.95 N. Table 3's results indicate that adding more threads per inch might result in a fabric that is comparatively stronger. Increasing the number of threads per inch may help boost the strength of extremely light materials.

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. BENEFITS OF CHANGED TAPIOCA STARCH FOR YARN SIZE

1. An environmentally friendly method and product for starch modification.
2. Offers a greater affinity for yarn.
3. Better yarn sizing performance compared to the carcinogen propylene oxide.
4. Less PVOH additives are used in sizing formulas.
5. Lowers the cost of sizing

CONCLUSION

Ozone and alkali were used to modify the starch of tapioca, maize, and potatoes. The most crucial factors to take into account while sizing yarns after treatment are viscosity, abrasion resistance, and tensile strength. According to the study of the results, tapioca starch that has had ozone and alkali added gradually has a lower viscosity (182 cps) than potato and maize starch. Compared to maize and potato starch, tapioca starch with a progressive addition of ozone and alkali has a greater abrasion resistance of 2200 CN/cm2. According to the results of a tensile strength test, as pick density rises, fabric assistance increases as weft count decreases. With the gradual addition of ozone and alkali treatment, tapioca starch outperforms maize and potato starch in terms of tensile strength among the three varieties of modified starch. The single yarn strength of tapioca starch with a stepwise addition of ozone and alkali was 8.89 N; when the pick density rose, the fabric assistance of the single yarn strength climbed to 8.95 N. It was determined that tapioca starch is the most effective size material for yarn sizing with the lowest sizing cost out of the three varieties of modified starch. There are no harmful residues released by this ecologically friendly method. Using a powerful weaving loom, the modified starch offers yarn size high strength, effective desizing, enhanced adhesion, and high abrasion resistance. All of these lead to superior fabric quality and better sizing.

***Department of Chemistry**
S.P.N.K.S. Govt. P.G. College
Dausa (Raj.)

REFERENCE

1. Nattapulwat N, Purkkao N and Suwithayapan O (2009),"Preparation and Application of Carboxymethyl Yam (Dioscorea esculenta) Starch" AAPS PharmSciTech vol-10(1), pp.193–198.
2. Q. Wei, Y. Xu and Y. Wang (2009), "Textile surface functionalization by physical vapor deposition (PVD)" Woodhead Publishing Series in Textiles Pages 58-90

3. Haque M (2009), "Effect of weft parameters on weaving performance and fabric properties" Daffodil international university journal of science and technology, VOLUME 4 (2), pp.62- 69.
4. Stegmaier T, Wunderlich W, Hager T, Siddique A B., Sarsour J, Planck H (2008), "Chitosan—A sizing agent in fabric production—Development and ecological evaluation" Clean vol-36, pp.279–286.
5. Sandhu K S., Kaur M, Singh N, Lim S., (2008), "A comparison of native and oxidized normal and waxy corn starches: Physicochemical, thermal, morphological and pasting properties" LWT, vol-41, pp.1000–1010.
6. Hebeish A, Aly A A., El-Shafei A M., Zaghloul S (2008), "Innovative Starch Derivatives as Textile Auxiliaries for Application in Sizing, Finishing", vol-3, pp.24-27..
7. Ashdown S P (2007), "Sizing in Clothing: Developing Effective Sizing Systems for ReadyTo-Wear Clothing; Textile Institute" Woodhead Publishing in Association with The Textile Institute: Manchester, UK,.
8. Maatoug S, Ladhari N, Sakli F (2007), "Evaluation of the weavability of sized cotton warps" Autex Res. J. vol-8, pp.239–244.
9. Kova cevic S, Penava Z (2004), "Impact of sizing on physico–mehanical properties of yarn. Fibres Text" East. Eur vol-12, 32–36.
10. Down J (1999), "Textiles Technology to GCSE" Oxford University Press: Oxford, UK.