Extraction and Optimization of Ethiopian Cassava Starch for Sizing

Chirato Godana, Muktar Seid Hussen
Ethiopian Institute of Textile and Fashion Technology (EiTEX), Bahir Dar University, Bahir Dar, Ethiopia,
Email: chiregod2008@gmail.com, henok1450@gmail.com

Abstract
Starch was the primary sizing agent for textiles at one time, and it is still used extensively either alone or in blends with other sizing agents. Starch occurs widely in plants, but it is found in the purest form in seeds (such as in wheat, corn, rice, and sorghum), in roots and tubers (such as in potato, tapioca, and arrowroot), or in the stem pith of plants. All starches have some unfavorable properties in terms of availability, extraction, energy use and agricultural activity while mixing one starch with another for optimization. In this study, starch is extracted from the root of the cassava plant using a simple and cost-effective method. Also, by taking 20.5Ne open end cotton yarn, yarn properties (strength, elongation and abrasion resistance) tests are carried out before sizing. After sizing of 20.5Ne open end cotton yarn with 100% cassava,100% maize,100% inset and 100% PVA separately, the main sizing effects are tested in terms of strength, elongation and abrasion resistance on sized yarn, and the performance of sizing materials are compared with each other. Data is then analyzed statically by calculating mean, variance, standard deviation and coefficient of variation of sized yarn properties. Optimization is also carried out using big-m method of minimizing cost with maize, cassava and inset; the optimized result is 67.33% cassava starch, 32.67% maize starch and zero inset starch. Again, sizing is done for optimal results and the properties of sized yarn are evaluated with optimized results. The optimal value can reduce the cost of raw material and improve the performance of sized yarn. Finally, desizing is approved using enzymatic desizing to check whether the starch is removable or not.
Keywords: *Cassava Starch, Extraction, Sizing Agents, Desizing, Optimization*

I. INTRODUCTION

Cassava is a tropical crop and its center of origin is believed to be the Amazon. Cassava is either planted as a single crop or inter-cropped with maize, legumes, vegetables, rubber, oil palm or other plants. Mixed planting reduces the danger of loss caused by unfavorable weather and pests by spreading the risk over plants with different susceptibilities. Cassava is a typical tropical plant. The approximate boundaries for its culture may be accepted as from 30ºN to 30ºS latitudes; however, most cassava growing is located between 20ºN and 20°S. In general, the crop requires a warm humid climate. Temperature is important as all growth stops at about 10ºC [8].

Cassava has many advantages for starch production; some of them are - high level of purity, excellent thickening characteristics, neutral (bland) taste, desirable textural characteristics, relatively cheap source of raw material containing a high concentration of starch (dry-matter basis) that can equal or surpass the properties offered by other starches (maize, wheat, sweet potato, and rice). For cassava, the process of starch extraction is relatively simple as there are only small amounts of secondary substances, such as protein in the roots [8]. There are several thousand varieties of cassava in Ethiopia with hydrogen cyanide (HCN) contents in their roots. Cassava plants are generally categorized as bitter or sweet depending upon their cyanide content. The low HCN or sweet cassava has less than 50 ppm of cyanogenic equivalents while the high HCN or bitter cassava has more than 100 ppm [2].

II. EXTRACTION

Cassava grows best on light sandy loams or on loamy sands which are moist, fertile and deep. It also does well on soils ranging in texture from sands to clays and on soils of relatively low fertility. In practice, it is grown on a wide range of soils provided the soil texture is friable enough to allow the development of the tubers. No fertilization is required when the land is freshly cleared and when there is enough land to enable the cultivator to substitute new land for old when yields fall. Like all rapidly growing plants yielding carbohydrates, cassava has high nutrient requirements and exhausts the soil very rapidly [8].

A simple, cost effective and suitable extraction method of starch from cassava plant's root is carried out by the following steps:

1) **Supply of cassava roots:** Cassava is available on farmland; the cassava plant roots are extracted from the soil when its first dug.
2) **Peeling and washing:** The general practice is to remove the peel (skin and cortex) and to process only the central part of the root, which is of much softer texture. The roots are cut longitudinally and transversely to a depth corresponding to the thickness of the peel, which can then be easily removed. Any dirt remaining on the

smooth surface of the core of the root can now be washed off without any trouble, and the peeled roots deposited in cement basins where they remain immersed in river water until taken out for rasping [5].

3) **Snapping:** Snap the root into two since there is a presence of wood matter inside the cassava. The wood matter and the roots are chopped off with sharp knives before the subsequent process.
4) **Chipping and washing:** The cassava root is then chipped into sizable particles. Any dirt remaining on the smooth surface of the core of the root can then be washed off without any trouble.
5) **Rasping and pulping:** It is necessary to rupture all cell walls in order to release the starch granules. This can be done by mechanical action. Mechanical action is carried out by slicing the roots and then rasping, grating or crushing them, which tears the flesh into a fine pulp. Hand rasping is carried out by placing the chipped root into a mortar with a stick.
6) **Settling:** This includes the whole series of operations for separating the pure starch from soluble contaminants. Settling is carried out to purify the starch by removing the water-soluble materials.
7) **Drying:** Drying is carried out by either natural sun drying for a certain amount of time or using the oven drying system. As the sun is the cheapest source of heat, the settled cassava is placed in sunlight to dry. The trays carrying the cassava can be placed on the ground itself, but it is preferable to place them above the ground. During the drying period, the tray should be covered with fabric to avoid the starch turning yellow.
8) **Milling:** The dried cassava starch is then grinded by mechanical means.

Figure 1: Cassava Plant

Figure 2: Cassava Root

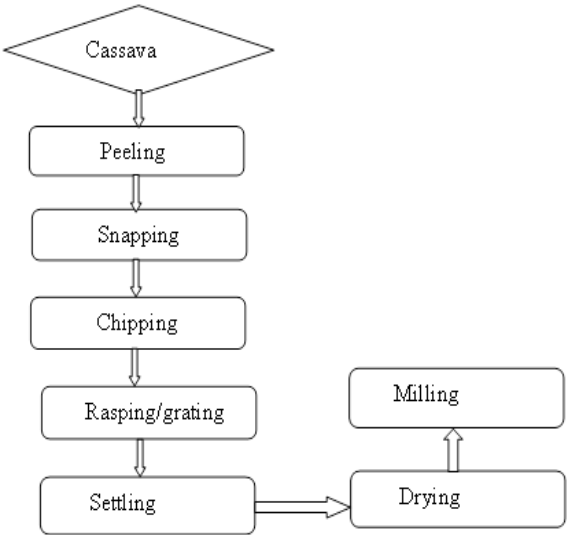


Figure 3: Extraction Method of Cassava Starch

III. METHODOLOGY

A. Methods

1) Size recipe preparation steps for 100% cassava:

- Pour 11.08 liters of water into the cooking tank.
- Add 1.108 kg of cassava and keep stirring for 7 minutes without heat.
- Keep stirring and apply heat to increase the temperature to 95^0C for 30 minutes.
- Let the prepared size paste into the size box.

2) Size recipe preparation steps for 67.33% cassava and 32.67% maize:

- Pour 11.08 liters of water into the cooking tank.
- Weigh 0.746 kg of cassava starch, add into the tank on cold water and keep steering for 7 minutes.
- Allow the stem to enter the cooking tank.
- Weigh 0.362 kg of the maize starch and add into the tank when the temperature reaches 72ºC.
- Set the cooking temperature at 95ºC and cook it for 30 minutes.
- Finally apply for size on the size box or store in a reserve tank.

3) Size recipe preparation steps for 100% maize:

- Pour 11.08 liters of water into the cooking tank.
- Set the cooking temperature at 95ºC.
- Allow the stem to enter into the cooking tank.
- Weigh 1.108 kg of the dry size and add in the tank when the temperature reaches 72ºC. This will help to remove deposition of size in the can.
- Cook it for 30 minutes.
- Finally apply for size on the size box or store in a reserve tank.

4) **Test procedure for strength and elongation:**

- Dynamometer single yarn strength tester.
- Collect representative yarn sample.
- Condition the sample in standard test atmosphere.
- Measure the yarn count preferably in indirect system.
- Guide the yarn through the yarn guide.
- Ensure that the upper jaw (J1) and lower jaw (J2) are in correct position. The distance between the two jaws should be 50 cm, the pointer on the extension scale should read zero.
- Guide the yarn through the upper jaw (J1) and tighten it.
- Guide the yarn through the lower jaw (J2) and tighten it with a nominal tension.
- Start the motor and record the breaking load and the breaking extension.

Table 1: Mean Test Result of Tensile Strength, Elongation and Abrasion Resistance

Test No.	Task	Tensile strength (cN/tex)	Elongation (%)	Abrasion Resistance (Revolution)
1	Un-sized yarn	367.725	5.9015	13
2	100% Cassava Sized Yarn	416.725	5.374	16
3	100% Maize Sized Yarn	402.25	6.257	14
4	100% Inset Sized Yarn	407.15	6.178	13
5	100% PVA Sized Yarn	418.575	6.272	17

As seen from the tests above, none of the starch materials fulfill the desired sizing parameters, so optimization is required to achieve the quality of sized yarn. This can be done by finding the optimum value of maize, cassava, inset and PVA starches as a maximum value; then blend the values of starch obtained in kilograms. Optimization is carried out by using big-m method through different iterations.

Table 2: Mean Strength, Elongation and Abrasion Resistance of Yarn Sized with Different Sizing Material for Iteration Calculation

Properties	100% Cassava	100% Maize	100% Inset	100% PVA
Mean Tensile Strength (cN/ tex)	416.725	402.25	407.15	**418.575**
Mean Elongation (%)	5.374	6.257	6.178	**6.272**
Mean Abrasion Resistance (Rev.)	16	14	13	**17**
Cost (Ethiopian Birr/Kg)	**9.5**	**10**	**18**	**36**

Let x (cassava), y (maize), and z (inset) be the number of units of P_1 (Price), P_2 (price), and P_3 (price) produced per kilogram respectively. The main objective is to minimize cost which is spent for sizing material through optimization of sized yarn properties.

- The objective function is minimize: $Z = 9.5x + 10y + 18z$
- Subject to constraints: $416.725x + 402.25y + 407.15z \geq 418.575$
  $5.374x + 6.257y + 6.178z \geq 6.272$
  $16x + 14y + 13z \geq 17$
- Non negative (decision variables): $x, y, z, \geq 0$

The optimal value of x, y and z is 0.746 kg, 0.362 kg and 0 kg respectively. Hence, the optimal value or the minimum cost of the sizing material is 10.704 Ethiopian Birr, i.e. 1.108 kg is equal to 10.704 Ethiopian Birr or 1 kg is equal to 9.663 Ethiopian Birr. From the feasible and optimal solution table, 456.37 cN/tex of mean tensile strength, 6.272% of mean elongation and 17 revolutions of mean abrasion resistance are expected theoretically. Finally, the optimal result of inset starch is zero, 67.33% cassava and 32.67% maize starch. After having the optimal value, sizing with the optimal result is carried out and tested for yarn properties. The optimal test results of sized yarn are 420.6 cN/tex in mean tensile strength, 6.1% in mean elongation and 16 revolutions in mean abrasion resistance.

Table 3: Data Analysis for 32.67% Maize and 67.33% Cassava Sized Yarn

Properties	Mean	Variance	SD	CV (%)
Tensile Strength (cN/Tex)	420.6	561.8	23.7	5.64
Elongation (%)	6.10	1.17	1.08	17.7
Abrasion Resistance (Rev.)	16	45.21	6.72	42.15

B. Materials

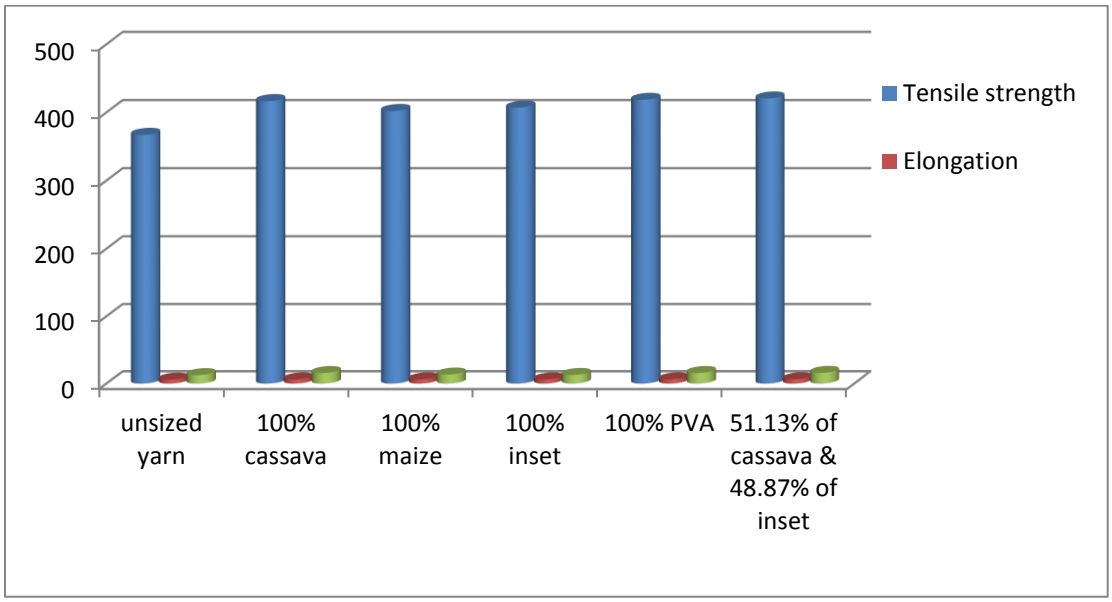
Cassava is extracted using mechanical method of extraction which does not need more energy and is a cost-effective method.

- Cassava plant root is supplied from farmland; the plant's root is grown deep in the ground; the soil is dug up, then the root is taken from the soil.
- 20.5 Ne open end cotton yarn.
- Conventional starches are already used for sizing in textile industries such as maize starch, inset starch and PVA starch.
- Materials used during extraction; knife for peeling, snapping and cutting, grey fabric for settling and also grinding machine during milling.
- Water used for extraction and sizing.
- Chemicals for desizing, enzyme biolase and sodium chloride.
- The properties of yarn are tested before and after sizing, and the equipment required for measuring these parameters are dynamometer strength tester and Abrasion or friction tester in EiTEX laboratories.

IV. RESULTS AND DISCUSSION

A. Results

Starch can be extracted from a wide range of plants such as root starches, corn starches, extracted synthetically, and can be modified to achieve different quality. In this study, starch is extracted from cassava plant's root. For comparison, we use already extracted starches which are used conventionally in Bahir Dar textile Share Company. These are maize, inset and PVA starches. The mean value for unsized yarn and sized yarn are graphically represented below.



Graph 1: Graphical Representation of Mean Test Result of Tensile Strength, Elongation and Abrasion Resistance

B. Discussion

As shown in Graph 1, the mean strength, elongation and abrasion resistance are obtained and show a visible difference between sized yarns of different sizing material. The unsized yarn has mean strength of 367.725 cN/tex which is less 49.525 cN/tex than cassava, 35.05 cN/tex than maize, 39.95 cN/tex than inset, 51.375 cN/tex than PVA and 53.4 cN/tex than the optimized result. Also, the unsized yarn has minimum elongation and abrasion resistance than the sized yarn with different sizing material.

The mean strength and abrasion resistance of sized yarn with cassava starch 416.725 cN/tex, 16 revolutions which is 14.475 cN/tex and 2 revolutions greater than that of sized yarn with maize respectively and 9.575 cN/tex and 3 revolutions more than that of inset starch respectively. Cassava has greater water bonding or thickening power, which makes it stronger and abrasive. Also, it has a strong bond between glucose molecules. The elongation of sized yarn with cassava 5.374% is 0.804% less than inset starch and 0.883% less than that sized with maize starch. We achieve higher penetration or paste clarity of cassava starch which affects extensibility of the yarn.

The mean strength of sized yarn with maize is 14.475 cN/tex less than cassava, 4.899 cN/tex less than inset and less 16.325 cN/tex than that of sized yarn with PVA starch. PVA achieves high strength because it creates a bond between fibers which increase the strength of yarn. The mean abrasion resistance of sized yarn of PVA is 17 revolutions which is greater by 1 revolution than cassava, 3 revolutions than maize and 4 revolutions than inset starch. Abrasion resistance is higher after sizing the gap between fibers which is filled with sizing agent and coating the outer surface of the yarn. The mean elongation of sized yarn with PVA starch 6.272% which is 0.015% greater than that sized with maize. Here, the elongation of yarn decreases as the material is stiff.

V. CONCLUSION

Natural starches are environment-friendly with respect to extraction of starches and application for sizing material. We conclude that the starch extracted from cassava requires limited capital, does not need fertilization, withstands a prolonged period of drought and is easily available.

Open end cotton yarn is sized with different sizing materials, and the yarn property is evaluated in our study. The results indicate that any good sizing materials cannot achieve all yarn properties; therefore, optimization is done by taking the price in one kilogram of maize, cassava and inset. Finally, the optimum size paste is carried out with blend of 67.33% of cassava starch and 32.64% of maize starch and zero percent of inset starch.

Therefore, optimization results in mean yarn strength of 420.6 cN/tex which is greater than sized yarn with 100% maize, 100% inset, 100% cassava and 100% PVA. And mean abrasion resistance is 16 revolutions, which is greater than that of sized yarn with 100% maize and 100% inset. But it has 6.1% elongation, which is less than all sizing materials except 100% cassava, and results in good yarn.

VI. ACKNOWLEDGEMENT

This work is supported by Ethiopian Institute of Textile and Fashion Technology (EiTEX) by giving all required laboratory equipment, reading material and internet access which is of great and valuable help to us.

VII. REFERENCES

[1]. Adepoju, O.T. and Nwangwu, J.O. Nutrient composition and contribution of noodles (abacha) and local salad from cassava (Manihot spp) to nutrient intake of Nigerian consumers. African Journal of Food Science. Vol. 4(7), 2010, 422-426.
[2]. Eke-Ejiofor J, Owuno F. The Functional Properties of starches, physicochemical and sensory properties of salad cream from cassava and potato. Int. J. Nutr. Food Sci., Vol. 3(6), 2014, 567-571.
[3]. B K Beheraa, Rajesh Mishra & Sanjay Nakum, Comparative analysis of size materials and their weaving potential, Indian Journal of Fiber and Textile Research, Vol. 33(2), 2008, 132-138.
[4]. James NB, Roy LW., Starch Chemistry and Technology, 3rd edition, Potato Starch Production, Modification and Uses, Academic Press. 2009, 511-539.
[5]. Radley. J .A. starch production technology. Applied Science Publisher's Science, London, 1976, 587.
[6]. Ranganathan, S. R., and B. C. Verma. "Laboratory evaluation of the performance of sized yarn." Textile Recorder, 1967, 34-35.
[7]. Patil, Yogesh B., Prafull P. Kolte, A. M. Daberao, and Bhavesh Sharma. "A critical analysis of airjet loom performance." Man-Made Textiles in India, Vol. 46(10), 2018, 350-353.
[8]. Rey Chrissie. Improvement of cassava for social and economic benefits. Southern African Society for Plant Pathology. 2006.
[9]. Root and tuber Starches Part I, Textile Research Journal, 1969, Vol. 39, 1044-1052.
[10]. Seydel, P.V., Hunt, J.R. Textile Warp Sizing; Phoenix Printing: Atlanta, GA, 1981.
[11]. Srinivas, T. Industrial Demand for Cassava Starch in India. Starch-Stark, Vol. 59, 2007, 477-481.
[12]. Goswami B.C., Martindale J. G., Scardino F. L., Eds.; John Wiley and Sons: Textile Yarns: Technology, Structure & Applications. New York, 1977.
[13]. Tennessee, Uster Statistics. Zellweger. Uster Publications: Knoxville: 1997.
[14]. Walters, A., Santillo, D. & Johnston, P. Greenpeace Research Laboratories, Department of Biological Sciences, University of Exeter, Exeter EX4 4PS, UK June 2005
[15]. Rakesh Patil, Sanjay Basak, Tushar C. Patil, Prafull P. Kolte, Role of Preparatory Process for Improving Loom Performance, Journal of the Textile Association, Vol. 79(3), 2018, 180-184.