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BADAY, ALEXANDER P. APRIL 2010. Dyes Derived from Sweet Potato (*Ipomoea batatas* Linnaeus) As Potential Dyes for Raw Silk from Mulberry Silkworm (*Bombyx mori* Linnaeus). Benguet State University, La Trinidad, Benguet.

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ABSTRACT

The study was conducted from December 2009 to March 2010 to determine if sweet potato can be a source of dyes for raw silk from mulberry silkworm (*Bombyx mori* Linnaeus). Three sweet potato varieties: Bengueta, Kawitan and Haponita particularly the leaves, stems, root flesh and root peelings were considered. The dye-extracts were applied to the raw silk and the resulting colors were determined using the textile color chart as standard.

Different colors were derived from the three varieties. The different plant parts also gave different colors ranging from light golden rod to steel blue. The color of the dyes changed when applied to raw silk. The colors became lighter ranging from cornsilk 3 to plum.

The fastness of the dyes on the raw silk need to be evaluated.

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INTRODUCTION

Sweet potato (*Ipomoea batatas* Linn.) is produced worldwide mainly in tropical regions. In the Philippines, this root crop ranks second in terms of volume production next to cassava (BAS, 2008). Benguet produced the highest average volume annual production which is 45% of the total amount production in the Cordillera region (Gonzales *et al*., 2006).

This crop is produced commercially for food. As sweet potatoes are excellent sources of carbohydrates and vitamins, it is also used for animal feeds. The demand for sweet potato is increasing. It is made into flour and a substitute for wheat flour in baking cakes and pastries. Peeling of the tubers would be utilized as dyes, feeds and compost materials (NPRCRTC, 1995).

Silk is a protein fiber extruded by the silkworm larva in a continuous filament as a cocoon. Raw silk is the product of processing cocoons. This product can be enhanced by the addition of color (Lijuaco, 1998). It has good affinity to dyes because its fibers are triangular and reflects like prisms, thus giving a beautiful dense color when dyed.

Dyes are classified as natural or synthetic. The textile industry has been importing most of its dyeing and other coloring material because of the absence of local manufacturers of either synthetic or natural dyestuffs. However, according to the Philippine DENR, the use of synthetic dyes causes the textile industry to discharge toxic waste into the water system, and is one of the main sources of environmental pollution (Fresco, 2004).

The PTRI developed a natural dyeing technology which includes the extraction of dyes from indigenous plant sources and their application to natural fibers, yarns and fabrics. To date, PTRI identified and established appropriate dyeing technology for 75 dye-yielding plants like sibukao, bakawan lalake, bakawan babae, loco roots, mahogany to name few (PTRI, n.d.)

The government should continue its efforts to resort ultimately to natural dyeing technology not only to cut the country's reliance on synthetic dye imports which prove to be ecologically degrading, but also to explore benefits that can be derived from indigenous sources which offer an eco-friendly alternative.

Sericulture practitioners are faced with the value adds on to their silk production, in order to dictate reasonable price. Limited research work has been done to explore the commercial potential of natural dyes from plant sources.

Thus, it is the aim of this study to help local silk producers identify and make use of indigenous plants as source of natural silk dyeing materials. This would minimize the value added cost to their product. Moreover, the use of natural dyes would be safe to man as well as to the environment.

The technology of natural dye production from sweet potato can be a sustainable source of income for farmers, as the prices of cash crops are very unstable coined with high cost of inputs.

The experiment was conducted to identify the dyes produced by the three sweet potato varieties, to know the color they can give the *Bombyx mori* L. raw silk and to document the study through photos. The study was conducted at Benguet State University, La Trinidad, Benguet from December 2009 to March 2010.

REVIEW OF LITERATURE

The Silk Material

Silk is a protein fiber extruded by the silkworm larva in a continuous filament as a cocoon. These cocoons are dried, sorted, directly cooked, reeled, re-reeled, hanked and booked for market, as raw silk (Caccam and Libunao, n.d.).

Raw silk is the raw material for silk production. Silk, the most in demand and popular among natural fibers serve as a second skin which contains 18 percent amino acids. Silk can prevent the absorption of ultra violet rays which causes skin cancer (Estolas, 1997). It has good affinity to dyes and its spectacular because its fibers are triangular and reflects like prisms, thus giving a beautiful dense when dyed (DMMSU-SRDI, 1996).

The universal appeal of colors led to a demand for huge volume of coloring substances by silk manufacturers. Whether natural or synthetic, silk industries rely heavily on dyes. These user-industries realize that their products can be enhanced by the addition of color (Lijuaco, 1998).

Silk Dyeing Technology

Dyeing is the process of imparting color on a material. A dye is a compound that can be adhered or fixed on a substance on materials like textiles, papers and cosmetics. The dyeing technology offered by PTRI are of two types: synthetic dyeing using commercially available dyes and natural dyeing which covers dye extraction from dye-yielding plants and its subsequent application on the materials (Alvarez, 2003).

In an excerpt retrieved from Pioneer Thinking Company (1999), the following methods are presented in making natural dyes from plants: chop plant material into small pieces and place them in a pot. Double the amount of water to the plant material. Bring to a boil, and then simmer for about an hour. Strain, now you can add your fabric to be dyed. For a stronger shade, allow material to soak in the dye overnight. For more efficient dye extraction, Lijuaco (1998) stated that chopping or grinding the dye sources is recommended except for seeds and dried leaves.

The fiber can be added to the dye bath. For most dyes, one may want to simmer the fibers in the dye bath for approximately 30 minutes, or until the color one wishes to achieve is reached. Obviously, the longer you leave the fiber in the dye the deeper or more intense the color will become. However, when you remove the dyed fibers from the dye-bath, after they are rinsed, the color will lighten. For this reason, the fibers in the dye-bath can be left longer to absorb more of the color. In rinsing the fiber remove the fiber from the dye-bath and rinse it in water approximately the same temperature as the dye-bath. Continue rinsing the fiber in progressively cooler water until the water is completely clear. At this point you should gently squeeze the fiber, dry or blot it gently in a towel (South Texas Unit of the Herb Society of America, n.d.).

Kolander (2003) came up with procedures on how to use natural dyes. First step is to extract the dye from barks, roots and dyewoods by soaking overnight, boil for half an hour, pour off and save the extract, this is the dye solution. Add more water and boil again and again as long as the dye plant parts continue to extract. Save the dye solution to make the dye bath. Dyeing the textiles is the second step which as follows: add enough additional water to the dye solution so the textile can move freely in the dye bath.

Add the textile and heat to hot. Heat for one hour or until the color reaches the desired depth. If the color is too light, use fore dyestuff.

Importance of Natural Dyes

As early in 1923, Small reported that by far, the greatest source of natural coloring materials is the plant world. He cited further that color can be extruded from limitless number of bark, roots, leaves, flowers, nuts and berries. The extraction and application methods of natural dyes offer an eco-friendly alternative. They are no-allergenic, do not contain carcinogenic substances nor emit pollutants during the process. Fresco in 2004 mentioned that common plants could help cut the Philippines reliance on imported synthetic dyes and reduce the pollution they cause. He added that the government should continue its efforts to go for the natural dyeing technology in order to explore benefits that can be derived from indigenous plant sources.

With the realization of the extent of ecological degradation worldwide, more stringent laws protecting the environment were passed. Hence, the search for “naturals” as alternative raw materials bridged the gap between natural dyes and erstwhile dominant synthetics (Lijuaco, 1998).

Fresco (2004) reported that the Philippine DENR claims that the textile industry discharge toxic wastes into the water systems, and is one of the main sources of environmental pollution. This is due to the use of synthetic dyes which are more abundant, cheaper and easier to apply than natural dyes. The use of the indigenous dyes from the plants is in line with the global consciousness on environment friendly processes and materials (PTRI, 1999).

Natural Dye Sources

The scientists, from the Philippine Textile Research Institute (PTRI) have identified twenty six species of plants including mangrove tree, a type of onion, guava and cashew nut trees that could be used to produce high quality natural dyes (Fresco, 2004).

PTRI developed the indigo dye powder production technology from malatayum (Indigofera tinctoria) It is the latest addition to twenty indigenous dye sources established by PTRI since 1992 (PTRI, 1999).

The dye extraction and application technologies for yellow ginger rhizomes, talisay leaves, malatayum leaves, atsuete seeds, buko husks, bulubulu leaves and betel nut seeds were transferred to and commercialized by the Federation of Banaue Weaver's Organization (PTRI, 2003).

Bunga de china, acacia, onion skin, golden shower, alig lalake, babae, neem tree and cashew leaves gave a satisfactory color fastness to a rating of 3 to 4.5 (PTRI, 2004). The cultural and management parameters for yellow ginger sibukao, indigo and annatto were explored and studied. Consequently, these technologies are ready for dissemination to various farmer cooperators who will respond to the growing requirement for the said dye sources in Aklan and in other parts of the country (PTRI, 2006).

As cited by Habal and De Guzman (2003) plant dye sources with optimized dyeing technology developed and being transferred by PTRI include duhat, hawili, kamachile, hapok, luam and sibukao.

Uses of Sweet Potato

Gonzales and Masangkay (2006) reported that 99.99% of the parts of sweet potato are consumed as food, the 0.01% is used as feeds or seeds. Traditionally, the crop has been the staple food for many mountain tribes especially in areas where rice is not readily available. The roots are chopped and dried into “buku” and mixed with wine.

Sweet potato is made into flour and partly used to substitute wheat flour for baking cakes and pastries. The flour/starch is imported to Korea for noodle making. Fresh sweet potato has been used as an ingredient of various products such as snack chips, catsup, pickles and candies that are fruit based jam beverage and wine (Gonzales and Masangkay, 2006).

In 1995, NPRCRTC reported information on the following uses of the different parts of the sweet potato plant. The leaves serve as vegetable for human consumption and feed stuff for the livestock industry. The stem in the form of cuttings are used as feed stuff for the poultry and livestock industry, for propagation in sweet potato production and fertilizer when composted. The root when boiled is for human consumption and could be made into home-made candies and delicacies. It could also be used as fees for chicken and livestock. Chips canned or plain, other confectioneries, flour starch and juice can be prepared from the roots. Vinegar, alcohol and wine are also by-products of the roots. The peelings of the root can be extracted for the production of dye for dyeing and coloring the textile and other chemical industries. Peelings would also be used as livestock feeds and compost material.

Gonzales in 2003 reported that NPRCRTC-BSU came up with a red wine made from dark purple-fleshed sweet potato, “Haponita”. Mature leaves are dark green while immature leaves are purple. When processed into wines, the sweet potato root is boiled and extracted into juice. In the process, the dark purple flesh turns to red which resembles the red commercial wine. Sp. Haponita has high anthocyanin content. These anthocyanin pigments are responsible for the color of red wines (Gonzales *et al*., 2006).

MATERIALS AND METHODS

Materials

The materials used in the study were sweet potato, raw silk from *Bombyx mori L.*, beaker (500 ml), white muslin cloth, stirring rod, wash bottle, empty glass bottle, mortar and pestle, knife, chopping board, liquefied petroleum gas stove and tank, wire gauze, triple beam balance, papers, ballpens, pentel pen, transparent polyethylene bags, stick and a digital camera.

Planting, Harvesting and Preparation of Sweet Potato

Three sweet potato varieties from NPRCRTC namely: Bengueta, Kawitan and Haponita were evaluated. These sweet potato varieties were planted and grown following the recommended cultural practices by the NPRCRTC at their experimental area. The sweet potatoes were planted on loamy soils in mounds, 25 cm high using one apical cuttings per hill with a length of 30 cm and with a distance of 100 x 25 cm between rows and hills, respectively. Fertilizer was applied 60-30-60 NPK kg/ha.

The sweet potato plants were harvested after 3 months from planting. Whole plant parts were taken and put in labeled polyethylene bags. In the laboratory, the plant parts were separated and washed thoroughly with tap water. The leaves were removed and placed in a labeled polyethylene bag. The stems were chopped and placed in different container. On the other hand the roots were thinly peeled using a knife. The flesh and the peelings were placed in separate containers also.

Extraction of Dyes

Twenty (20) grams of each plant part are used. To extract the dyes the plant parts were chopped into little pieces then crushed using the mortar and pestle. These were placed separately in 500 ml beaker filled with 400 ml tap water. The specimens were boiled for one hour, stirred once every five minutes with the use of the stirring rod. After one hour of boiling, the solution was strained by pouring the solution into the white cloth at the top of the glass bottle opening. Then the white cloth with the solid part of the solution is squeezed in the glass bottle when the temperature is bearable.

Dye Application to Raw Silk

The extracted liquid dye was poured to the beaker. The 4 g of silk was moistened in the tap water, squeezed and then added to the liquid dye extract. The solution was heated at the gas stove with full volume for 35 minutes, stirred twice in every 5 minutes using the stirring rod. After 35 minutes of boiling, the beaker was placed in the sink and filled with cold tap water. Then the silk was washed by squeezing and moistening and so on until the squeezed water is clean. The dyed raw silk was loosened and air dried for 3 days.

Plant Material Preparation to Dyeing

Figures 1 to 30 shows the photo documentation in preparing the plant part material until the dyeing of the raw silk.

Figure 1. Materials used for extracting the dyes

Figure 2. Materials used for the dyeing process

Figure 3. Harvested Bengueta variety plants

Figure 4. Harvested plants of Kawitan variety

Figure 5. Haponita variety plants harvested at NPRCRTC

Figure 6. The researcher manually harvesting the kawitan
variety plant

Figure 7. Segregating the leaves by plucking it upward from the base of the petiole

Figure 8. Chopping of the stems for easier weighing

Figure 9. Leaves of Bengueta variety

Figure 10. Chopped stems of the Bengueta variety

Figure 11. Peeled enlarged roots of the Bengueta variety

Figure 12. Root peelings of the Bengueta Variety placed in a plastic bag for weighing

Figure 13. Leaves of the Kawitan variety

Figure 14. Chopped stems of Kawitan variety

Figure 15. Peeled roots of the Kawitan variety put in plastic bag

Figure 16. Root peelings of the Kawitan variety

Figure 17. Leaves of Haponita variety

Figure 18. Chopped stems of the Haponita variety

Figure 19. Root flesh of the Haponita variety

Figure 20. Root peelings of the Haponita variety

Figure 21. Weighing the 20 grams root flesh in the triple beam balance at the Soils Science Laboratory

Figure 22. Chopping the root peelings to facilitate extraction of dyes

Figure 23. Crushing the chopped stems for efficient and faster extraction of the color

Figure 24. Transferring the crushed leaves to a beaker with 400 ml water

Figure 25. Stirring the boiling water with chopped root flesh

Figure 26. Pouring the 1-hour boiled plant part in the white muslin cloth to strain the extract

Figure 27. The liquid dye extract is transferred to the beaker for dyeing

Figure 28. The extracted dye with the raw silk is in the beaker being heated

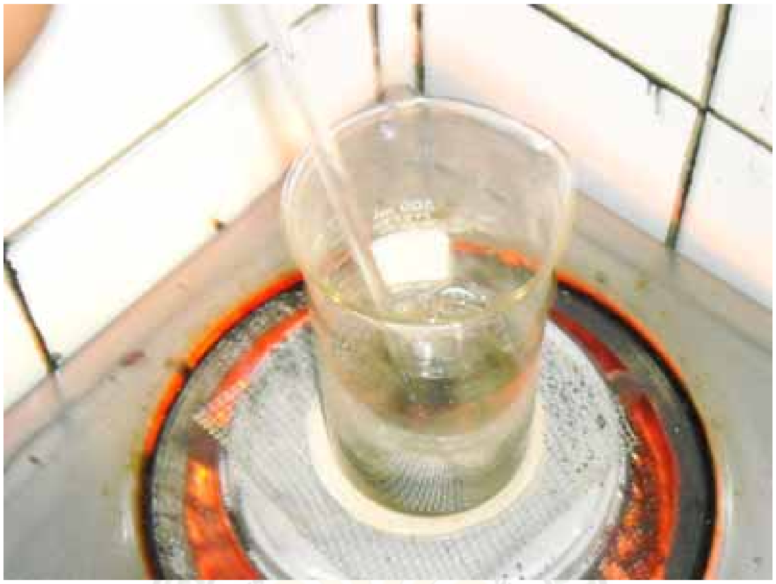


Figure 29. A stirring rod was used to stir the silk while the solution is boiling

Figure 30. The dyed raw silk is washed in a flowing tap water until the squeezed water is clean

Data Gathered

The following data were gathered:

1. Identified colors derived from the sweet potato varieties. The colors were determined using the textile color chart.

2. Specific colors yielded by the different parts of the sweet potato plant. The colors given by the dyes extracted from the different parts to the raw silk were recorded using the textile color chart. Twenty grams of each plant part were pounded and transferred to the beaker with 400 ml water then boiled for 1 hour. The solution was strained and the extract is set aside. Four grams of silk is added to the extract and boiled for 35 minutes with frequent stirring. The silk materials are washed thoroughly with tap water squeezed and air-dried. Textile color chart was used to determine the color of the dyed raw silk.

RESULTS AND DISCUSSION

Dyes Extracted from the
Sweet Potato Varieties

The colors extracted from the sweet potatoes varied from light golden rod to steel blue as shown in Table 1. Similarly the different plant parts that were extracted produced varied color. The dye extracted from the leaves of Bengueta variety is green yellow while the stem gave yellow green. On the other hand, the roots whether it be the flesh or peelings produced light golden rod. The same plant parts in the Kawitan variety produced the same color with that of the Bengueta variety. In the case of Haponita variety, it was different. The root flesh and root peelings gave steel blue. This color is attributed to its high anthocyanin content that gives red color dye to the wine produced from this variety (Gonzales, 2003).

Table 1. Color of fresh dyes from three sweet potato varieties

VARIETY	PLANT PART	DYE COLOR
Bengueta	Leaves	Green yellow
	Stems	Yellow green
	Root flesh	Light golden rod
	Root peelings	Light golden rod
Kawitan	Leaves	Green yellow
	Stems	Yellow green
	Root flesh	Light golden rod
	Root peelings	Light golden rod
Haponita	Leaves	Green yellow
	Stems	Yellow green
	Root flesh	Steel blue
	Root peelings	Steel blue

The finding shows that sweet potato can be a source of natural dyes. The leaves and stems regardless of the variety produce green yellow and yellow green, respectively. The Bengueta and Kawitan varieties produce the same color but not in the case of Haponita.

Dyes Extracted from Sweet potato and
Applied to Raw Silk

The colors derived from the three varieties of sweet potato were used to dye the raw silk from *B. mori*. The result of the dyed raw silk is shown in Table 2. The differences among the varieties are discussed below.

Bengueta variety. The dyes extracted from the leaves gave the raw silk a cornsilk 3 color. The dye from the stem gave a beige color while the root flesh and root peelings of this variety gave the same color to the raw silk which was Margie.

The results show that the 4 parts of Bengueta variety can give color to the raw silk. This variety gave 3 different colors which are cornsilk 3, beige and Margie.

Kawitan variety. The extracted dye from the leaves gave the raw silk a citrus color while the other parts gave different colors. The dye from the stem gave a serenity color to the raw silk. Both the root flesh and the root peelings gave a Margie color to the raw silk.

This variety also gave 3 different colors which are citrus, serenity and Margie.

Haponita variety. The extracted dye from the leaves of this variety gave a sunshine yellow color to the raw silk. The extracted dye from the stem gave a color Margie when applied to raw silk. Both the root flesh and the root peelings gave a plum color to the raw silk. The finding corroborate with what Gonzales in 2003 reported that

Table 2. Color of dyed raw silk extracted from three sweet potato varieties

VARIETY	PLANT PART	COLOR OF DYED RAW SILK		
		Replication 1	Replication 2	Replication 3
Bengueta	Leaves	Cornsilk 3	Cornsilk 3	Cornsilk 3
	Stems	Beige	Beige	Beige
	Peeled Roots	Margie	Margie	Margie
	Root Peelings	Margie	Margie	Margie
Kawitan	Leaves	Citrus	Citrus	Citrus
	Stems	Serenity	Serenity	Serenity
	Peeled Roots	Margie	Margie	Margie
	Root Peelings	Margie	Margie	Margie
Haponita	Leaves	Sunshine yellow	Sunshine yellow	Sunshine yellow
	Stems	Margie	Margie	Margie
	Peeled Roots	Plum	Plum	Plum
	Root Peelings	Plum	Plum	Plum

"Haponita" variety which is used in making the wine produced natural red color which resembles the red wine and the anthocyanin pigments responsible for the color given

All the dyes extracted from the 4 parts of Haponita gave color to the raw silk. This variety gave sunshine yellow, margie and plum color to the raw silk.

The result of the study on the three varieties agrees on the NPRCRTC (1995) report that the peelings of the sweet potato can be extracted for the production of dye.

Comparison of Fresh Dye
from Processed Dye

The fresh dye refers to the solution derived from sweet potato after boiling while the processed dye refers to the dye appearing on the raw silk after dyeing.

Table 3 shows that the fresh dyes from the Bengueta variety changed after they were applied to the raw silk. The green yellow dye from the leaves became cornsilk 3 which is lighter. The same was true on the other dyes. The results were the same on the Kawitan variety. The fresh dyes changed color when applied to the raw silk and the resulting colors are lighter. In the case of Haponita variety, it was observed that the results do not differ from the other two varieties.

The results observed on the three varieties of sweet potato imply that the dyes derived from them may not be stable when further boiled. It is not also certain that the colors from this plant will remain fast for a long time. Figures 31 to 42 shows the photo documentation of raw silk dyed with the plant parts of 3 varieties of sweet potato.

Table 3. Color of fresh dye from sweet potato and the dyed raw silk

VARIETY	PLANT PART	COLOR OF FRESH DYES	COLOR OF DYED RAW SILK
Bengueta	Leaves	Green yellow	Cornsilk 3
	Stems	Yellow green	Beige
	Root flesh	Light golden rod	Margie
	Root peelings	Light golden rod	Margie
Kawitan	Leaves	Green yellow	Citrus
	Stems	Yellow green	Serenity
	Root flesh	Light golden rod	Margie
	Root peelings	Light golden rod	Margie
Haponita	Leaves	Green yellow	Sunshine yellow
	Stems	Yellow green	Margie
	Root flesh	Steel blue	Plum
	Root peelings	Steel blue	Plum

a)

b)

c)

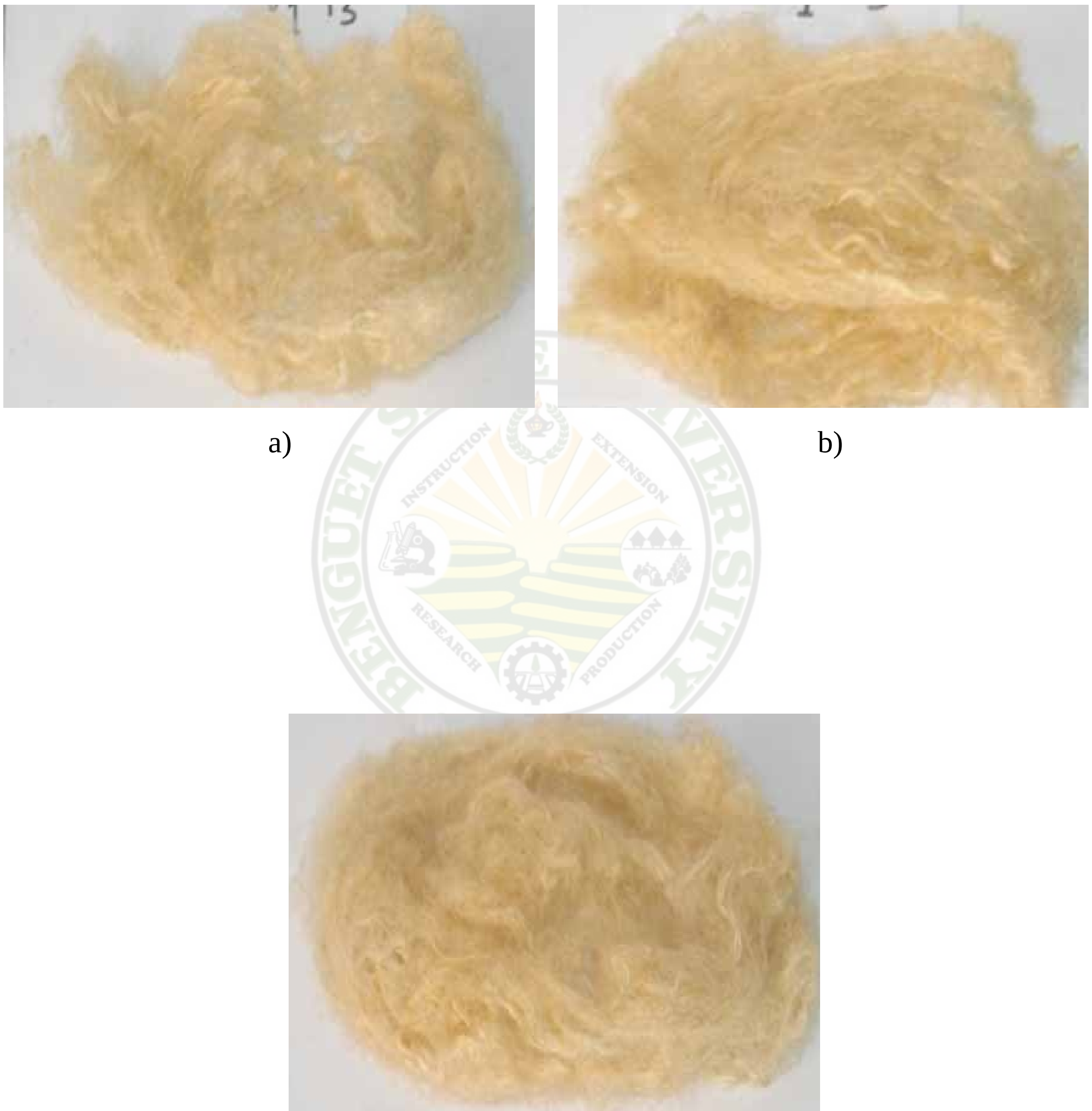
Figure 31. Raw silk dyed from the dye extracted from the leaves of the Bengueta variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

a)

b)

c)

Figure 32. Raw silk dyed from the dye extracted from the stems of the Bengueta variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3



a) b)

c)

Figure 33. Raw silk dyed from the dye extracted from the root flesh of the Bengueta variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3


a) b)

c)

Figure 34. Raw silk dyed from the dye extracted from the root peelings of the Bengueta variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

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a) b)

c)

Figure 35. Raw silk dyed from the dye extracted from the leaves of the Kawitan variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3


a)


b)


c)

Figure 36. Raw silk dyed from the dye extracted from the stems of the Kawitan variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

a)

b)

c)

Figure 37. Raw silk dyed from the dye extracted from the peeled roots of the Kawitan variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

a) b)

c)

Figure 38. Raw silk dyed from the dye extracted from root peelings of the Kawitan variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

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a)

b)

c)

Figure 39. Raw silk dyed from the dye extracted from the leaves of the Haponita variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

a) b) c)

Figure 40. Raw silk dyed from the dye extracted from the stems of the Haponita variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

a)

b)

c)

Figure 41. Raw silk dyed from the dye extracted from root flesh of the Haponita variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

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a)

b)

c)

Figure 42. Raw silk dyed from the dye extracted from the root peelings of the Haponita variety of sweet potato: (a) replication 1, (b) replication 2 and (c) replication 3

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The colors of the dyes derived from three sweet potato varieties and the colors produced when applied to *Bombyx mori* L. raw silk were determined from December 2009 to March 2010. The sweet potato varieties used were Bengueta, Kawitan and Haponita planted and grown at NPRCRTC.

Each plant was segregated into four parts namely leaves, stems, root flesh and root peelings and were tested for the colors yielded upon extraction and application to the raw silk. Each plant part was replicated 3 times.

Extraction is done by chopping and crushing the plant part and boiling it for 1 hour. The extract is strained and their color was determined with the use of a textile color chart. The raw silk is added and boiled for 35 minutes. This is done to all the segregated plant part of the different varieties. The dyed raw silks are air dried for 3 days and their colors were determined also with the use of the textile color chart.

Conclusions

Based on the results of the study, it is concluded that the 3 sweet potato varieties namely Bengueta, Kawitan and Haponita are good dye sources because they can produce various colors with their different parts such as leaves, stems, root flesh and root peelings and their colors changed when applied to the raw silk of *Bombyx mori* L. The colors became lighter.

Recommendations

Based on the results and conclusions of the study, the following recommendations were made:

1. Further studies should be conducted to check the color fastness of the dyes produced and the effect of the dyeing process to the quality of silk.

2. Other sweet potato varieties and other dye-yielding plants should also be studied on the dye-color they can produce.

3. The dyes produced should also be tested with other commodities like cosmetics and foods.

4. If it is so desired that the color of the fresh dyes will be achieved, it is recommended that a study will be conducted on how their color can be stabilized.

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