Arrowroot (*Maranta Arundinacea*): Starch Extraction, Processing, and By-Products Utilization

Michael V. Capiña and Verna Liza L. Capiña

Abstract—The storage roots called rhizomes of Arrowroot (*Maranta Arundinacea*) vary in size and number depending upon the soil, climate and age of the plant. Rhizomes are the main source of starch that are easily digested when extracted and produces a dry white powder. This powder is a source of one of the purest form of natural carbohydrates which is considered gluten free and superior quality starch used in making the first class biscuits, pastries, pudding, cakes, native Filipino delicacies and many more. In Marinduque, Philippines arrowroot cookies are one of the most popular "pasalubong" or food products produced from arrowroot starch. For every one kilo of arrowroot rhizomes, starch recovery commonly ranges from 10-20% depending on its quality. This study resulted only to 13% or 390 grams dried starch recovery using 3 kilograms of fresh rhizomes, while water produced amounted to 59% and remaining 28% went to waste rhizomes or "sapal". Waste from water can be developed into wine while grinded rhizomes or "sapal" into flour, handmade paper, and novelty items. Proximate analysis shows that waste rhizomes flour contains 11.39% moisture, 2.71% ash, 1.27% crude protein, 0.05% crude fat, 6.12% crude fiber, and 78.46% nitrogen-free extract. Nutrition fact per serving size of 100 grams shows 320 calories, 0 fat, 78 grams carbohydrates, 6 grams dietary fiber and 1 gram protein. Two arrowroot wine samples were also tested which resulted to alcohol content of 7% and 9% respectively while physical testing of handmade paper from "sapal" shows poor quality. To increase starch recovery, further research and studies should be done focusing on pre and postharvest activities and facilities on how to minimize losses and maximize volume of starch recovery. Conversely, potential to utilize waste water into bioethanol and biogas may also be considered. Arrowroot waste flour can be developed into human and animal feed substitutes and additives as food ingredients while the arrowroot waste fiber into textile and construction materials. Considering the foregoing, the utilization of arrowroot starch by-products foresees positive impacts and adds value for arrowroot that may lead to increased price and productivity.

Keywords— Arrowroot waste rhizomes flour, arrowroot wine, proximate analysis, nutritional facts

I. Introduction

Arrowroot *(Maranta arundinacea)* locally known as "*uraro*" in Marinduque, Philippines is a minor crop that grows in hilly areas under coconut grooves but almost 50-60% of its biomass and residues are wasted. Arrowroot starch extracted from the rhizomes is digestible and an important ingredient of biscuits and cookies which is popularly utilized by many local bakeries for production of arrowroot cookies, a popular specialty product of the province of Marinduque, Philippines. Arrowroot starch has a very high commercial value, gaining economic value, and market share for both local and export market.

Processing of arrowroot starch extracted from the rhizomes is laborious and tedious. A manual and inefficient mechanical extraction process of starch results to low percentage of starch recovery of about 10-20%, but the remaining 90-80% can be considered by-products.

Prices of both rhizomes and starch are uncompetitive. The prevailing price of rhizome ranges from 5.00 to 7.00 pesos per kilo that further varies on the location of the farmers. The price of starch per kilo ranges from 55.00 to 150.00 pesos but because the actual buying practice in the province is per ganta or salop which is equivalent to 2 to 2.2 kilograms, prices of starch in the province range to an average of 55.00 to 75.00 pesos per kilo. Thus, this study was conducted to add value, increase benefits, and discover other uses of by-products from arrowroot starch extraction.

II. Materials and Methods

To be able to utilize by-products and develop other products from the arrowroot starch extraction process, the following activities were performed:

1. During arrowroot starch extraction, waste were collected, set-aside, and quantified;
2. The identified wastage was developed into flour, wine, handmade paper, and potential novelty items;
3. Subjected to laboratory test the identified waste of rhizomes or "sapal" flour for proximate analysis, sugar, and nutrition facts while arrowroot wine for alcohol content; and
4. Handmade paper undergone physical testing conducted by PhilFIDA FUTD, a government agency pioneering and developing fiber resource of the Philippines to conduct laboratory analysis.

Simple statistical analysis of data gathered was used, complemented with interview, and field survey.

III. Results and Discussion

A. Process of Starch Extraction

1. Methods of Starch Extraction

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Michael V. Capiña is with the Marinduque State College, School of Business and Management and School of Agriculture, Fisheries and Natural Resources, Tanza Boac, Marinduque, 4900 Philippines

Verna Liza L. Capiña is with the Marinduque State College, School of Business and Management, Tanza Boac, Marinduque, 4900 Philippines

There are basically two methods of starch extraction being practiced by the arrowroot farmers in the province of Marinduque. One is through the traditional method, locally known as *ilod*, other is through the use of motor-operated grinder machine.

The traditional method is being utilized by arrowroot farmers in Barangay Malbog, Beunavista, Marinduque. This method uses a big lumber which when rolled over another two big lumbers at both ends cause crushing of the arrowroot rhizomes (Figure 1).

Figure 1. Traditional Method of Starch Extraction

Due to the laborious and tedious process of the traditional method, the farmers discovered the use of motor operated arrowroot grinder fabricated equipment as shown in Figure 2.

Figure 2. Motor operated arrowroot grinder

2. Establishment of Arrowroot Processing Facility

At the early year of 1997, DA-Marinduque requested assistance from Bureau of Postharvest Research & Extension (BPRE) in improving arrowroot starch extraction. In 1999 PSTC-Marinduque through DOST-IVB provided technology and financial assistance through its Small Enterprise Technology Upgrading Program (SETUP) by establishing an arrowroot processing facility in Lipa, Sta. Cruz Marinduque which was now owned and operated by one of the pioneer and number one producers of arrowroot cookies in the province. The processing center consists of the following: washer, extractor, centrifuge/spinner, dryer, settling tank, and weighing scale. Most of the machines were manufactured by KOLBI, an agricultural machinery firm in Bicol Region, and were designed by Dr. Malinis of Bicol University, the same person who assisted the mechanization of the said facility in Lipa Sta Cruz.

3. Process Flow Diagram of Arrowroot Starch Extraction

Extraction of starch from the rhizomes entails several processes as shown in Figure 3. It includes four major activities namely: (1) cleaning and cutting of rhizomes into small cubes (2) extraction procedure using prototype grinding machine, (3) washing of grinded rhizome and sieved using fine cheesecloth, (4) drying of settled starch, and (5) refining of starch using fine nets (MVCapina et.al, 2016).

Figure 3. Process flow chart of arrowroot starch backyard processing

B. Identification and Quantification of Waste During Starch Extraction

Processing of arrowroot starch extracted from the rhizomes is laborious and tedious while a manual and inefficient mechanical extraction process result to low percentage of starch recovery of about 10-20% and 90-80% by-products. During the arrowroot starch extraction, waste were collected, set-aside, and quantified. The result revealed a low dried starch recovery of 13% or 390 grams out of 3 kilograms of fresh rhizomes. The water produced after extraction amounted to a huge percentage of 59% while waste rhizomes or “sapal” amounted to 28%, Table 1 (MVCapina et.al, 2016).

Table 1. Identified Arrowroot Waste from Starch Extractions

Sample	In Grams	Percentage
Starch	390	13%
Waste Rhizome (Sapal)	830	28%
Water	1,780	59%
Total	**3,000**	**100%**

C. Arrowroot Starch Waste Product Development

1. Flour from waste rhizomes or “sapal”

About 28% waste rhizomes or sapal is being produced in every arrowroot starch extraction. A big percentage of the waste is not being utilized by the processors and farmers, but few used this as feeds for their native pigs and chicken. Most of the time, these farmers use fresh sapal to feed pigs. But there are times they dry the sapal for storing and then boil the dried sapal for a few minutes before feeding pigs. Shown in figure 4 is the process flow diagram of utilizing sapal into flour for possible product development for human and animal consumption.

Figure 4. Process flow diagram of utilizing "sapal" into flour

2. Wine from waste water after washing of grinded rhizomes

A huge percentage or about 59% of waste from starch extraction process is water. Mrs. Carmelita R. Reyes, owner of Rejanos Bakery that pioneered the production of arrowroot cookies since 1955 and became one of the popular bakeries in Marinduque, and who also owns an arrowroot processing center with the assistance of DOST Marinduque, experimented the utilization of waste water into wine. Using two bottles of wine samples (Figure 5) as testers, analysis resulted to 7% and 9% alcohol content respectively.

3. Handmade Paper and Novelty Items from waste rhizomes or "sapal"

The arrowroot wastes identified were developed into different novelty items and products as presented in Figures 5 and 6.

Figure 5. Arrowroot Wine from Waste Water and Handmade Paper

Figure 6. Novelty Items from waste rhizomes or "sapal"

D. Proximate Analysis And Nutrition Facts and Alcohol Content

According to wisegeek.com, "Proximate analysis is a scientific analysis done to determine the approximate amounts of substances within a material. This is utilized to study such things as food, animal feed, coal, and bio-fuels. This information can be used to create quality controls for various materials, ensure that they do not contain hazardous chemicals, and determine whether they are healthy enough to be consumed by humans or animals." The material further pointed out one major goal of proximate analysis is "to determine if there are hazardous substances in a sample of material and find out if food items are safe for human and animal consumption." (*http://www.wisegeek.com/what-is-proximate-analysis.htm)*

Results of proximate analysis, waste rhizomes flour is comparable to arrowroot starch with 11.39% moisture content, 2.71% ash, 1.27% crude protein, 0.05% crude fat, 6.12% of crude fiber, and 78.46% nitrogen-free extract as seen in table 2.

Table 2. Proximate Composition of Arrowroot Starch and Flour Waste Rhizomes "Sapal"

Parameters	**Arrowroot Starch**	**Flour Waste Rhizomes (Sapal)**
% Moisture	13.1 ± 0.25	11.39 ± 0.07
% Ash Content	0.16 ± 0.05	2.71 ± 0.01
% Crude Fat	0.25 ± 0.04	0.05 ± 0.01
% Crude Protein	0.83 ± 0.02	1.27 ± 0.01
% Crude Fiber	0.03 ± 0.01	6.12 ± 0.83
% Nitrogen Free Extract	85.6	78.46

*As analyzed by Food Chemistry Lab. IFST, UPLB

Table 3 shows nutrition facts per serving size of 100 grams have 320 calories, 0 fat, 78 grams carbohydrates, 6 grams dietary fiber and 1 gram protein. This can be a basis for further study and product development for food and animal feeds.

Table 3. Nutrition Facts of Flour Waste Rhizomes "Sapal"

Nutrition Facts

Serving Size: 100g
Servings per Container:

Amount per Serving		
Calories 320		Calorie from Fat 0
		% Daily Value*
Total Fat 0g		0
Total Carbohydrates	78g	26
Dietary Fiber	6g	24
Total Sugars	0g	
Protein	1g	2

*Percent Daily Values are based on a 2,000 calorie diet
Calorie per gram: Fat=9, Carbohydrates=4, Protein=4
*As analyzed by Food Chemistry Lab. IFST, UPLB

E. Chemical Properties and Physical Testing

1. Chemical Properties of Waste Rhizomes "Sapal"

Chemical properties are the properties of fiber related to their inherent chemical components which have profound influence in processing and usefulness of the fiber. These properties are determined through analyses of the chemical contents of a fiber like ash, silica, lignin, holocellulose, alphacellulose, and hemicellulose and its solubility in alcohol-benzene, hot and cold water and 1% NaOH.

Table 4. Chemical Properties of Waste Rhizomes as Fiber

Fiber Sample	Moisture (%)	Ash (%)	Solubilities in (%)			Lignin (%)	Cellulose (%)		
			Acetone	1% NaOH	Hot H_2O		Holo	Alpha	Hemi
Waste Rhizome	9.86	5.46	0.29	39.43	18.45	8.48	78.65	42.12	28.13

*As analyzed by Philippine Fiber Industry Development Authority Fiber Utilization and Technology Division

Ash represents the non-volatile, non-combustible inorganic element such as silica, calcium, manganese, potassium, and other salt contents of a fibrous material. Excessive ash content (generally over 2.0%) may indicate a corresponding high silica content which is main components of scale deposit that may reduce the operational efficiency of a machine in pulp mill. Extractives are extraneous components in lingo-cellulosic material present in a fiber. Fibrous materials with high extractives (5% and over using alcohol-benzene and hot water) are generally undesirable for pulping since they consume more pulping chemicals and have lower pulp yield. Solubility in 1% NaOH determines the resistance of a fiber to NaOH by hot dilute alkali test. It also indicates the degree of fungal decay in a fibrous material. Those fibers with 22% and higher solubility in 1% NaOH are generally susceptible to fungal decay and yield markedly lower pulp. Lignin is an amorphous polymeric natural product which acts as the cementing substance that gives rigidity to the cell walls of the fibers. The acceptable lignin content is less than 30% in general and higher values require higher amount of chemicals. Holocellulose is the total polysaccharides content of a fibrous material. It includes alphacellulose, beta and gamma cellulose, and hemicelluloses. In general, fibers with 65% holocellulose are desirable for pulp and papermaking. Fibers with holocellulose values lower than 65% are considered as low pulp yielders according to PhilFIDA, Fiber Utilization and Technology Division.

2. Physical Testing of Handmade Paper from Waste Rhizomes "Sapal"

According to PhilFIDA Fiber Utilization and Technology Division, the following are the reasons why pulp and paper are tested: 1. for efficient process and product quality control, 2. for consistency and correspondence with relevant quality specifications, 3. to describe numerically certain relevant properties or features of the product, its intermediate or both, and 4. to obtain property values for use in marketing a product. The results revealed that extracted fibers and pulp have poor formation properties, uneven thickness and surface roughness, and have low bonding strength (Table 5). But this can be improved by enhancing the quality of handmade paper following the standard developed by PhilFIDA, like using technology base process, chemicals, and other binding agents that will help improved the quality of paper.

Table 5. Physical Testing of Handmade Paper from Waste Rhizomes "Sapal"

Sample / Parameters	Handmade Paper
Air Permeability, Gus	0.420
Thickness, µm	1410
Density (bulk), kg/m^3	257
Basis Weight , g/m^2	326.8
Tear Index, $mN.m^2/g$	9.4
Tensile Index, Nm/g	4.44
% Elongation	3.41
Folding Endurance at 65 gsm, (double folds)	1.0

Testing Conditions: 50.0 $\pm$ 2% RH and 23.0 $\pm$ 1^0C

* As analyzed by Philippine Fiber Industry Development Authority Fiber Utilization and Technology Division

IV. CONCLUSIONS AND RECOMMENDATION

The extraction process of arrowroot starch from the rhizomes is laborious and tedious while a manual and inefficient mechanical extraction process result to low percentage of starch recovery of about 10-20% considering 90-80% by-products. There are bulks of agricultural waste left unutilized by the arrowroot starch processor which can be turned into more useful products through value-adding. Very low starch recovery hampers the productivity resulting to minimal expansions which further hinder the product to compete in the world market. Increasing starch recovery needs further research and studies focusing on; pre and postharvest activities and facilities on how to minimize losses and maximize volume of starch recovered.

During the trial, only 13% or 390 grams dried starch out of 3 kilograms of fresh rhizomes was recovered. A huge percentage of waste from starch extraction process was water which is almost 59% out of fresh rhizomes. Potentials to utilize waste water into wine with 7% and 9% alcohol content and for other products such as bioethanol and biogas should be considered for further study and enhancement.

Results of proximate analysis and nutrition facts per serving size of 100 grams of waste rhizomes flour is comparable to arrowroot starch. This can be a basis for further study and product development for human and animal consumption as substitutes and additives as food and feeds ingredients. The arrowroot wastes identified which were further developed into different novelty items and products through value adding also foresee potentials but must be creative enough to conceptualize a more competitive product promoting green entrepreneurship.

While the potentials for paper and pulp are below standard, this can be used for other purposes such as textile and fly board for construction materials considering its chemical properties. Further research can be done to promote arrowroot waste rhizomes that will provide other source of income and employment opportunities.

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Michael V. Capiña a native of Lopez, Quezon, Philippines, and born on November 4, 1977. A graduate of Bachelor in Agribusiness Management at Polytechnic University of the Philippines Lopez Branch in year 1998, Master in Management Major on Agribusiness Management at University of the Philippines Los Banos, Laguna in year 2008, and currently enrolled in Ph.D. in Management at Adamson University, Manila, Philippines. He is currently an Assistant Professor IV at the Marinduque State College with 16 years in service, teaching in the School of Business and Management and the School of Agriculture, Fisheries and Natural Resources. He is formerly the Dean of the said schools from 2013 to 2015 and from 2011 to 2012 respectively. He presented and published papers about buntal and buri palms as an output of funded projects from Commission on Higher Education (CHED) in 2011 and arrowroot industry funded by Bureau of Agricultural Research in 2013.

Verna Liza L. Capiña, a native of Mogpog, Marinduque, Philippines, born on June 29, 1976, and earned Bachelor, Master, and Doctoral degrees in Business Administration from the Pamantasan ng Lungsod ng Maynila, Intramuros, Manila, Philippines in 1996, 2000, and 2015, respectively.

She is currently an Assistant Professor III at the Marinduque State College with 15 years teaching experience originally from the School of Agriculture, Fisheries and Natural Resources. She is at present a faculty and concurrent Dean of the School of Business and Management. Her research interests also include cooperative management and development.