

**EXTENDING THE USE OF A HIGHLY NUTRITIOUS
UNDERUTILISED TARO (COLOCASIA ESCULENTA) TUBER BY
DEVELOPMENT OF TUTTI FRUITY**

**Abdul Sabir^{*1}, Desham Kodandaram Reddy², Dr. Kavita Waghray³ and Vellenki
Bhaskar⁴**

¹M.Tech Food Technology, University College of Technology (A), Osmania University,
Hyderabad 500007, Telangana, India.

²Assistant Professor (C) Department of Technology (Food Technology) University College of
Technology (A) Osmania University Hyderabad- 500007, Telangana, India.

³Professor Former Head of Food Technology Department of Technology (Food Technology)
University College of Technology (A) Osmania University Hyderabad- 500007, Telangana,
India.

⁴Assistant Professor (C), Department of Technology (Food Technology), University College
of Technology (A), Osmania University, Hyderabad-500007, Telangana, India.

Received on 28/05/2017

Article Revised on 12/06/2017

Article Accepted on 27/06/2017

***Corresponding Author**

Abdul Sabir

M.Tech Food Technology,
University College of
Technology (A), Osmania
University, Hyderabad
500007, Telangana, India..

ABSTRACT

Tutti Fruity or Indian candied fruits are made from various chopped fruits and vegetables, and it is used in Cakes, Bun, Muffins, Cookies, Bread, and Custard & Ice-Cream. In this present work Taro (*Colocasia esculenta*) is used to prepare, because Taro is found to be highly nutritious and an underutilised tuber which also reduces the sugar level in the body. The raphides (needle like crystals) of calcium oxalate are

responsible for the itching and the irritations during the handling and the consumption of Taro (*Colocasia esculenta*) tuber. However, the utilization options of Taro are mainly limited to direct consumption as whole boiled or pounded tuber only, thus making it an underutilized crop. In this literature an effort has made to reduce the itching caused by raphides (Needle like crystals of calcium oxalate) and to develop a new product from Taro (*Colocasia esculenta*) by means of 3 samples (1, 2, 3) in 3 steps (Blanching at 90°C for 3mins, Boiling at

100°C for 30mins and 60mins) and sensory evaluation conducted for all 3 samples including control sample. All 3 samples (1, 2 and 3) are subdivided into 10, 5 and 4 sub samples respectively and each subsample is assigned with a particular alphabet. Samples(1a,1b,1c,1d,1e,1f,1g,1h,1i) blanched at 90°C for 3mins with Tamarind pulp at concentrations of 5%(1a), 10%(1b), 15%(1c), 20%(1d), 25%(1e), 30%(1f),40%(1g), 50%(1h), 60%(1i) and sample(1j) blanched in water at 90°C for 3mins. Samples (2a,2b,2c,2d) boiled at 100°C for 60mins with Tamarind pulp at concentrations of 30%(2a), 40%(2b), 50%(2c), 60%(2d) and Sample(2e) boiled in Water at 100°C for 60mins. Samples (3a,3b) boiled at 100°C for 30mins with Salt solution at concentrations of 2.5%(3a), 5%(3b) and samples(3c,3d) boiled at 100°C for 60mins with Salt solution at concentrations of 2.5%(3c), 5%(3d). The sensory evaluation showed that Tutti Fruity made from Sample2d boiled at 100°C for 60mins at 60% concentration of Tamarind pulp is superior in overall acceptability at 1% significance level ($p<0.01$) when compared to control sample. Sample1i blanched at 90°C for 3mins at 60% concentration of Tamarind pulp and Sample 3f boiled at 100°C in water for 60mins are inferior to sample2d. Sample2d was accepted and superior to all samples in overall acceptability and maximum number of panel members i.e., 26 panel members out of 30 found that there was no itching after consumption of Sample 2d.

KEYWORDS: Taro (*Colocasia esculenta*), Tamarind pulp, Salt solution, Tutti Fruity, Physicochemical properties, Sensory evaluation, Ranking Test, Fiducial limits.

Table of Contents

S.No	Topic	Page No
1	Acknowledgement	i
2	List of Tables	ii
3	List of Figures	iii
4	Abstract	iv
5	Aim and Objective of Work	vi

CHAPTER-1

1	INTRODUCTION	01
1.1	Uses of Taro (<i>Colocasia esculenta</i>)	03
1.2	Ethnic Taro (<i>Colocasia esculenta</i>) Products	04

CHAPTER-2

2	LITERATURE REVIEW	06
2.1	Kinetics of Calcium Oxalate Reduction in Taro (<i>Colocasia esculenta</i>) Corm Chips during Treatments Using Baking Soda Solution	07
2.2	Changes during before and after cooking of Taro (<i>Colocasia esculenta</i>)	07

2.3	The effect of temperature on the calcium oxalate concentration in taro corm cubes	08
2.4	Preparation of sugar treated cubes from other food sources	09
2.4.1	Starch	09
2.4.2	Moisture	09
2.4.3	Protein	10
2.4.4	Fat	10
2.4.5	Crude fibre	10
2.4.6	Total ash	11
2.4.7	Mineral	11
2.4.8	Vitamins	11
2.5	Health Benefits of Taro	12
2.5.1	Phytochemicals	12
2.5.2	Phenolic Acids	12
2.6	Antinutritional factors limiting utilization of Taro	12
2.6.1	Mucilage	12
2.6.2	Oxalic Acid/Oxalates	13
2.6.3	Protease (Trypsin and Chymotrypsin) inhibitors	15
2.6.4	Lectins	15
2.6.5	Alpha amylase inhibitors	15
2.7	Processing of Taro in to different products	16
2.8	Drying methods suitable for Taro	16
2.8.1	Taro flour	18
2.8.2	Taro chips	19
2.9	Calcium Oxalate Reduction in Taro (<i>Colocasia esculenta</i>) Corm Chips during Treatments Using Baking Soda Solution	21
2.10	Effect of Fermentation on Physicochemical Properties and Oxalate Content of Cocoyam (<i>Colocasia esculenta</i>) Flour	22
2.11	Changes during before and after cooking of Taro (<i>Colocasia esculenta</i>)	22
2.12	The effect of temperature on the calcium oxalate concentration in Taro corm chips	23
2.13	Preparation of sugar treated cubes from other food sources	24
2.14	Physicochemical Properties	25
2.14.1	Effect of Pre-treatment and Storage Condition on the Physicochemical Properties of Taro (<i>Colocasia esculenta</i> [L.] Schott) Flour	25
2.14.2	Effect of boiling time on chemical composition and physico-functional properties of flours from Taro (<i>Colocasia esculenta</i>) corm	25
2.14.3	Effect of processing method on the proximate composition, mineral content and antinutritional factors of Taro (<i>Colocasia esculenta</i> , L.)	26
2.14.4	Studies on Effects of Processing on Oxalate Content in Agricultural Produce (<i>Colocasia esculenta</i> , <i>Prunus dulcis</i> , <i>Glycine max</i>)	27
2.14.5	Physical and Chemical characteristics of Taro [<i>Colocasia esculenta</i> (L.) Schott] Corms and Processing to Chips and Puree	27
CHAPTER-3		
3	MATERIALS AND METHODS	29
3.1	Collection and preparation of Taro corm cubes	29
3.2	Preparation of Tutti Fruity from Taro corms	29
3.3	The process flow chart	32
3.4	The process flow diagram	33

3.5	Sensory evaluation	36
3.6	Ranking test using Fiducial limits	38

CHAPTER-4		
4	RESULTS AND DISCUSSION	39
5	CONCLUSIONS	47
6	REFERENCES	49
7	APPENDICES	59

LIST OF TABLES

S.No	Topic	Page No
1	Proximate composition of Taro corm on fresh weight basis	05
2	Percentage composition of Taro corm Carbohydrate	05
3	Step1 (Blanching in Tamarind pulp and water at 90°C for 3mins)	30
4	Step2 (Boiling in Tamarind pulp and water at 100°C for 60mins)	31
5	Step3 (Boiling in Salt solution for 30mins and 60mins)	31
6	Sensory evaluation of Taro Tutti Fruity (Mean \pm Standard deviation)	39
7	Presence of itching yes/no of all samples by Sensory evaluation data	40
8	Mean value of all samples in terms of overall acceptability parameter by sensory evaluation data	41
9	Overall rank of all samples in terms of overall acceptability by sensory evaluation data	43
10	Calculation of fiducial limits of control sample in terms of overall acceptability	62

LIST OF FIGURES

S.No	Title	Page No
Fig 1	Taro (<i>Colocasia esculenta</i>) corm	03
Fig 2	Step 1-Blanching in Tamarind Pulp at 90°C for 3mins	33
Fig 3	Step 2-Boiling in Tamarind Pulp at 100°C for 60mins	34
Fig 4	Step 3-Boiling in Salt solution at 100°C for 30mins and 60mins	35
Fig 5	Control sample	37
Fig 6	Samples of Step1 (Blanching in Tamarind pulp and Water at 90°C for 3mins)	37
Fig 7	Samples of Step2 (Boiling in Tamarind pulp and Water at 100°C for 60mins)	37
Fig 8	Samples of Step3 (Boiling in Salt solution at 100°C for 30mins and 60mins)	37
Fig 9	Pie chart for mean value of all samples in terms of overall acceptability parameter by Sensory evaluation data	42
Fig 10	Bar graphs for rank of all samples in terms of overall acceptability parameter by Sensory evaluation data	44

AIM AND OBJECTIVE OF WORK

1. The objective of this work was to investigate the effect of different solution concentrations, times and temperatures on the itching (calcium oxalate) reduction during boiling of taro corm in Tamarind pulp and Salt solution. An acquisition of understanding of the taro corm processing to reduce itching (calcium oxalate) content to a safe level may demonstrate its further potential uses in the food industry as an alternative source to conventional forms of carbohydrates or in production of new food products.
2. Therefore, it is important to investigate whether the calcium oxalate content in the taro corms can be reduced by preparation and cooking with Tamarind pulp and Salt solution to a safe level.

1. INTRODUCTION

Taros (*Colocasia* spp.) are stem tubers which are native to India and Malay Peninsula and are now cultivated throughout in both the tropical and subtropical regions of the world. In fact, among seven species of *Colocasia* which are originated from Asia, *Colocasia esculenta* is the most grown in India, Indonesia and other Southeast Asian countries (Ihekoronye *et al.*, 1985). Taro yields high quantities of energy and protein. The soft white-fleshed Taro corms, usually called Taro roots, are highly valued as a staple food and are eaten boiled, fried, roasted, fermented or turned into flour ("fufu" in West Africa), bread and biscuits. Low-grade corms are also used for alcohol production (Safo Kantaka *et al.*, 2004; Wilson *et al.*, 1996).

Due to their oxalate content, it is recommended to soak, wash or cook Taro corms and dry before consumption (Pheng Buntha *et al.*, 2008a; Babayemi *et al.*, 2009).

In India all the plant parts of *Colocasia esculenta* are used as vegetable as well as medicinal purpose among the rural peoples. It is also a source of economic increment to the farmers. The plant is also referred as a commercial crop. Many flavonoids and steroids have been isolated from *Colocasia esculenta* Linn. The plant is grown in India for especially its corm, leaves etc. India is marked as a center of origin of this plant (Onwueme *et al.*, 1994). In addition, taros have also been important crops in Hawaii, Japan, Egypt, Ghana and Nigeria. Most taro cultivars taste acrid and can cause swelling of lips, mouth and throat if they are eaten raw (Bradbury *et al.*, 1998). The acidity of taro is thought to be concentrated in the outer layers of the corm and may be largely removed by peeling off a thick layer followed by prolonged boiling (Sakai *et al.*, 1983). This acidity is learned to be caused by calcium oxalate presents as fine needle-like crystals or raphides, which can penetrate soft skin

(Bradbury *et al.*, 1998). Thereafter an irritant presents on the raphides, probably a protease can cause discomfort in the tissue (Paull *et al.*, 1999). The two common toxic effect of oxalate poisonings are (1) acute poisoning, resulting in hypocalcaemia (low calcium levels in the blood serum) after ingestion of high levels of soluble oxalates, and (2) (more commonly) chronic poisoning in which calcium oxalate crystals are deposited in the kidneys, resulting in renal disorder (kidneys fail to adequately filter metabolic wastes from blood). In addition, the presence of oxalate in foods has also been implicated in reducing the bioavailability of essential minerals such as calcium (Kelsav *et al.*, 1985).

The oxalates are widely distributed in the plants in readily water-soluble forms, such as potassium, sodium, and ammonium oxalate and as insoluble needle like calcium oxalate crystal (Smith *et al.*, 1982). Since calcium may also present in the plants in the form of soluble calcium oxalate crystals. Boiling can reduce the soluble oxalate content of a food if the cooking water is discarded, while soaking, germination and fermentation will also reduce the content of soluble oxalates (Noonan *et al.*, 1999). In contrast, baking a food will cause an effective concentration of oxalates in the food due to the loss of water from the baked food (Noonan *et al.*, 1999).

Taro corm is served either as staple or mixed with other vegetables, usually after cooking. Iwuoha *et al.*, (1995) suggested that appropriate cooking may reduce the harsh and sharp irritation in the throat and mouth. Cooking may improve digestibility, promote palatability, improves keeping quality, and also makes root crops safer to eat (FAO *et al.*, 1990). The types of cooking methods (boiling, pressure cooking and baking) differ in many areas of the world and also vary with the ethnic background of the family (Bhandari *et al.*, 2006). Fresh taro corm is difficult to store and is vulnerable to deterioration during storage. Because it is regarded as a health food and is a staple food extensively eaten in the Pacific Islands and in the rural areas of India, it is feasible to develop a stable form of taro products to fulfill the health food market. One of the best ways to preserve it is by processing it into flour and/or starch (Perez *et al.*, 2005).



Fig 1: Taro (*Colocasia esculenta*) corm.

1.1 Uses of Taro (*Colocasia esculenta*)

Taro usage can be similar to that of potato in the western world and corms can be converted into several specific food products and also for industrial purposes. Processes for stabilizing and adding value by conversion to semi-finished and end products include boiling, roasting, baking, frying in oil and pasting, milling and pounding. Arnaud-Vinas *et al.*, (1999) have also considered the possibility of production of pasta from blends of wheat and Taro flours.

A typical common product is the Ghanaian fufu-a pounded mass of boiled Taro. It is also used in soup thickeners and baking flours, in beverages, as porridge and in producing foods for people with gastrointestinal disorders (Hussain *et al.*, 1984, Ihekoronye *et al.*, 1985, Obiechina *et al.*, 1987, Onwueme *et al.*, 1978).

Taro chips are an important product and young Taro leaves are an excellent vegetable and in the South Pacific, incorporated with coconut cream to prepare a dish called “luau”, which consumed with boiled or roasted Taro, breadfruit and banana (Opara *et al.*, 2000). Roasted or boiled corms can also be eaten alone or with stew.

1.2 Ethnic Taro (*Colocasia esculenta*) Products

Poi- Poi is a purplish paste of cooked Taro produced in Hawaii (Hong *et al.*, 1990). It undergoes natural fermentation or is eaten unfermented. Occasionally, sugar and milk are added before consumption.

Achu- A meal made from pre-gelled Taro flour, in a process studied by Njintang *et al.*, 2003 is traditionally prepared by a combination of peeling, boiling, pounding and mashing in a mortar to obtain a paste. Achu is a valued food product in Cameroon (Njintang *et al.*, 2003).

Sapal- It is a fermented meal prepared with Taro corms and coconut cream in a process described by Gubag *et al.*, 1996. (Paul *et al.*, 1999).

Table 1: Proximate Composition of Taro corm on fresh weight basis.

Component	Content
Moisture	63-85%
Carbohydrate (mostly starch)	13-29%
Protein	1.4-3.0%
Fat	0.16-0.36%
Crude Fibre	0.60-1.18%
Ash	0.60-1.3%
Vitamin C	7-9 mg/100 g
Thiamine	0.18 mg/100 g
Riboflavin	0.04 mg/100 g
Niacin	0.9 mg/100 g

Source: Onwueme *et al.*, 1994

Table 2: Percentage composition of Taro corm Carbohydrate.

Carbohydrate	Percentage (%)
Starch	77.9
Pentosans	2.6
Crude Fibre	1.4
Dextrin	0.5
Reducing sugars	0.5
Sucrose	0.1

Source: Onwueme *et al.*, 1994

2. LITERATURE REVIEW

Taro is used as a staple food or subsistence food by millions of people in the developing countries in Asia, Africa and Central America. Taro has much importance in ensuring food security, in earning foreign currency as being a cash crop and also as a means for rural development. Nutritionally, Taro contains more than twice the carbohydrate content of potatoes and yield 135 kcals per 100 g. Taro contains about 11% protein on a dry weight basis. This is more than yam, cassava or sweet potato. Many authors also stated that the protein content of taro is higher than the other root crops in leaves and tuber respectively. It contains 85-87% starch on dry matter basis with small granules size of 3-18 μm and other

nutrients such as minerals, Vitamin C, thiamin, riboflavin and niacin better than other cereals. The high protein content of the leaves favorably complements the high carbohydrate content of the tubers. In other parts of the world, the leaves of *Colocasia esculenta* have been reported to be rich in nutrients, including minerals such as calcium, phosphorus, iron, and vitamins like vitamin C, thiamine, riboflavin and niacin. High levels of dietary fiber in taro are also advantageous for their active role in the regulation of intestinal transit, increasing dietary bulk and faeces consistency due to their ability to absorb water. Most rural peoples suffer from malnutrition not because of the economic status but because of inability to utilize the available nutritious raw materials to meet their daily requirements. Now a day, zinc deficiency is widespread and affects the health and well-being of populations worldwide and since taro is one of the few non animal sources of zinc, its utilization should therefore be pursued to help in the alleviation of zinc deficiency which is associated to stunting.

Taro belongs to Aroid family (Araceae) and it is in the genus *Colocasia*. It is widely produced throughout the world for its underground corms (Njintang *et al.*, 2007). Plants of the genus *Colocasia* are edible aroids with large leaves and one or more food storing in their underground stems (corms) (Adane *et al.*, 2009). Taro plant is best planted in soil with pH around 5.5-5.6 and in an environment that is high in humidity with rainfall level of 1000 mm each year and optimum temperature around 21-27 °C (Anonymous *et al.*, 1999). Because of a long history of vegetative propagation, there is considerable confusion in the taxonomy of the genus *Colocasia*. Cultivated taro is classified as *Colocasia esculenta*, but the species is considered to be polymorphic. There are at least two botanical varieties; *Colocasia esculenta* (L.) Schott var. *esculenta* and *Colocasia esculenta* (L.) Schott var. *antiquorum* (Schott).

2.1 Origins and production of taro

Taro originates from humid tropical rainforest regions of Southeast Asia including India. Different researchers conclude that it is not possible to determine a single centre of origin for taro (Lebot *et al.*, 1999). Evidence from the highlands of Papua New Guinea, indicates that taro processing was active by at least 10, 000 years, while *Alocasia* and *Colocasia* starch residues have been found on stone implements from Buka, Solomon Islands that date back some 28000 years ago . The species is now found throughout the Pacific islands and worldwide. The bulk of world production of taro is in Africa, followed by Asia and then Oceania. The major producers in Asia are China, Japan, Philippines and Thailand; while in

Oceania, production is dominated by Papua New Guinea, Samoa, Solomon Islands, Tonga and Fiji (FAO *et al.*, 1999).

2.2 Nutrition and other importance of Taro

The nutritional value is the main concern when a crop is being considered as a food source. Due to the emphasis placed on the nutritional value of food by consumers, a great need exists for information on the nutritional contents of root crops (Huang, *et al.*, 2007). The high starch content of most root crops is considered as an excellent energy source, but they are marginal to poor sources of protein. Root crops contain a wide variety of minerals and trace elements, including relatively substantial quantities of iron and calcium, as well as potassium and magnesium. Root crops are usually a good source of vitamins, e.g., yellow cultivars of the sweet potato or giant swamp taro are considered to provide ample b-carotene (Huang, *et al.*, 2007). Starch is the most important component (73-80%) of taro (Njintang *et al.*, 2007). Taro proximal composition varies depending on the variety, growing conditions, kind of soil, moisture and fertilizer application, maturity at harvest, post-harvest management and storage. In general, protein and fat content at corm are low but it is high in carbohydrates, fiber and minerals. About 11 % of the total protein in taro is albumin with high amounts of phenylalanine and Leucine. The protein of taro is well supplied with hundred essential amino acids though in low histidine and lysine (Arnavid-vinas *et al.*, 1999).

Although the roots are the most widely consumed and important parts of the plant, the leaves, and rhizomes of taro are eaten depending on the cultivar and the culture. In Asia/ Pacific regions, for instance, the leaves are usually boiled and or prepared in various ways mixed with other seasoners. Taro can be consumed as boiled, baked, roasted or fried and in conjunction with fish, and coconut preparations (Jane *et al.*, 1992). Taro flour in precooked forms may find good uses in pastry filling, binder in sausage and as emulsifier in food systems.

2.3 Nutritional quality and Chemical composition of Taro

The nutritional composition of taro corm like other root crops is low in protein and low in fat, but high in the carbohydrate. It is a good source of potassium and provides moderate level of phosphorus. It is low in vitamin C and deficient in the vitamins A. Taro corm is a good source of minerals and the small granule size of its starch helps increase the bioavailability of its nutrients due to efficiency of digestion and absorption (Standal *et al.*, 1983).

2.4 Chemical composition of Taro

2.4.1 Starch

Taro corm has been reported to have 70-80% (dry weight basis) starch with small granules (Jane *et al.*, 1992). Because of the small sizes (1-4 μm in diameter) of its starch granules, taro is highly digestible and as such has been reported to be used for the preparation of infant foods in Hawaii and other Pacific islands (Jane *et al.*, 1992). Taro starch is considered to be easily digestible; hence it is widely used in baby foods and the diets of people allergic to cereals and children sensitive to milk. Taro starch, in view of its small granule size, has also been used for industrial applications. Taro starch is easily digestible, the starch grains are fine and very small, it has hypoallergenic nature (low tendency to cause allergic reactions) (Jane *et al.*, 1997; Kochhar *et al.*, 1998) and also the starch is gluten free.

Taro starch is also good for peptic ulcer patients, patients with pancreatic disease, chronic liver problems and inflammatory bowel disease and gall bladder disease (Emmanuel-Ikpeme, *et al.*, 2007). The size of the starch granules varies with the variety and ranges from 1.5 to 6.6 μm . The shape is polygonal. Taro starch contains about 50% less amylose and an amylopectin content which is higher compared to other cereals. The amylose/amylopectin ratio is 1:7. The taro starch forms a clear and soft paste similar to potato starch. Starch gelatinization temperature is dependent on the variety as well as of the maturity at harvest and is lower as the age increases, ranging from 63-73°C. The most important sugar in taro is sucrose, but fructose, maltose, glucose and Raffinose are also present. Malic acid is the most important organic acid (60%) followed by citric acid (25%) and oxalic acid (15%) (Arnavid-vinas *et al.*, 1999).

2.4.2 Moisture

Since taro is root crop its moisture content is very high and accounts two third of the total weight of the fresh crops (FAO *et al.*, 1999). Moisture content of taro varies with variety, growth condition and harvest time. In general the moisture content of taro ranges from 60-83% (Huang *et al.*, 2007).

2.4.3 Protein

Taro contains about 11% protein on a dry weight basis. This is more than yam, cassava or sweet potato. The protein fraction is rich in essential amino acids of trionine, Leucine, Arginine, Valine and phenylalanine. Among the essential amino acids methionine, lysine, Cystine, phenylalanine and Leucine are relatively abundant in the leaf than the corm. The

protein content of the corm is higher towards the corm's periphery than towards its centre. This implies that care should be taken when peeling the corm; otherwise a significant amount of the protein could be lost in the peeling.

Taro composes high protein than other root crops because of the presence of symbiotic soil bacteria in the root and rhizome part of taro. These bacteria fix atmospheric bacteria and increase nitrogen occurrence in the corm and leaf (Lucy *et al.*, 2004). More over the bacteria used as plant growth enhancer due to release of growth hormone to root and distributed to the whole part of the plant. The free-living nature of these soils bacterial also helps the taro crop to grow at different environmental and ecologic conditions (Lucy *et al.*, 2004). These properties have economic and ecologic important to the environment.

2.4.4 Fat

As many other root and tuber crops the fat content of taro is very low and its fat content is mainly composed, of the lipids of the cell membrane and it is also variable among cultivars. In general the fat contents of taro root range from 0.3-0.6% (FAO *et al.*, 1999).

2.4.5 Crude fiber

Taro contains both dietary and non-dietary fiber. In a research conducted on six cultivars of taro in Cameroon and Chad it was found that the crude fiber content of taro ranges from 0.3-3.8% (FAO *et al.*, 1999). Also in another study conducted in six cultivars of taro grown in American Samoa the total soluble and insoluble fiber of taro even a larger range from 5.02-9.01% (Nip *et al.*, 1989). Crude fiber has many desirable functional properties. These include facilitating alimentary functions, helping in micro-component delivery and glucose metabolism and also slowing down the process of re-absorption of undesirable dietary components such as cholesterol, decrease intestinal transit time, and reduce total and LDL cholesterol in the blood, decrease post prandial blood glucose and insulin level, buffer excessive acid in the stomach, prevent constipation, increase water holding capacity of food, increase stability of food by modifying structure and density of food, textures the food, gel formation in the food, thickening capacity in the food.

2.4.6 Total ash

Taro contains fairly high amount of ash. From which it can be inferred it contain good mineral contents. The ash contents of taro ranged from 3.54 - 7.78%.

2.4.7 Mineral

Taro is a good source of minerals including iron (8.66-10.8 mg/100g), calcium (31-132mg/100g), sodium (82-1521.34mg/100g), magnesium (118-415.07mg/100g), phosphorus (72.21-340mg/100g), zinc (2.63mg/100g), copper (1.04mg/100g) and an excellent source of potassium (2271-4276.06mg/100g). High potassium to sodium ratio food recommended for patient with high blood pressure.

2.4.8 Vitamins

Vitamin C and vitamin B complex (niacin, riboflavin and thiamin) which are important constituents of human diet, are present in appreciable quantity in corms and leaves of taro. Like other roots and tubers are deficient in most other vitamins but contain significant amounts of dietary fiber. Cooked leaf of Taro contains beta carotene, iron and folic acid which protects against anemia (FAO *et al.*, 1990). There are about 1530 calories in one pound of Malanga (*xanthosoma*) flour (Jirarat *et al.*, 2006). The composition of Malanga flour is approximately: 75.5% carbohydrates, 5.1% protein, 1.6% fat, 9.8% fiber, 1.2% water and 6.8% minerals.

2.5 Health benefits of Taro

2.5.1 Phytochemicals

Taros have high amount of β -carotene in the corm and will impart vitamin A and antioxidant property in the body. β -carotene differs only very slightly in terms of structure. They are very common carotenoids, and are antioxidants, as well as having other potential health benefits. As mentioned earlier, both can be converted into vitamin A by the body, though β -carotene has about twice the provitamin α activity as α -carotene (Nip *et al.*, 1997).

2.5.2 Phenolic acids

These are simple phenolic acids that are widely distributed in the cell walls of plants and consequently are significant components of the human diet. They have been studied largely in relation to antioxidant activity though these have been largely in vitro studies and further work regarding in vivo effects in humans is needed before health benefits can be claimed. Yellow-fleshed cultivar of taro is associated with a high level of total phenolic compounds.

2.6 Anti-nutritional factors limiting utilization of Taro

Anti-nutrients which found in taro root have negative implications for taro as a food, yet they also have positive implications for taro as a crop that can be grown with minimal use of

fungicides and pesticides. The main antinutrients that exist in taro are: mucilage, oxalic acid, tannins, cyanide, lectins, alpha-amylase inhibitors, protease (trypsin and chymotrypsin) and inhibitors (Ramanatha et al., 2010).

2.6.1 Mucilage

When raw taro corms are cut in to pieces, the exposed surfaces often exude droplets of a slimy substance called mucilage. The pieces or slices of corm are washed or placed in portable water; a great quantity of mucilage is quickly released or avoided. The crude mucilage is a complex mixture composed mainly of neutral polysaccharides, with small quantities of fiber and protein (Nip et al., 1997). Mucilage can be removed by discarding the water used for cooking, or acid ingredients such as lemon juice can be used to neutralize the slimy effect, or the taro can be cooked without water (e.g. fried or baked) in a manner that leads to partial dehydration and a dry texture. However, the mucilage in taro corms are important for health because of digestibility and lower blood cholesterol by binding bile, slow blood glucose, slow transit of food through upper GI tract, absorb water and hold moisture that soften stool (Hollyer et al., 1997).

2.6.2 Oxalic acid / Oxalates

Oxalates are one major limiting factor in the utilization of taro is the presence of oxalates which impart acrid taste or cause irritation when raw or unprocessed foods from them are eaten. This acidity is caused by needle-like calcium oxalate crystals, raphides that can penetrate soft skin (Bradbury et al., 1998). Thereafter an irritant present on the raphides, probably a protease can cause discomfort in the tissue (Bradbury et al., 1998). High oxalate concentrations in the leaves and corms of plants consumed daily are of concern because of the harmful health effects associated with the intake of high amounts of oxalates (Savage et al., 2007). In large quantities, oxalic acid is poisonous to humans and can also reduce the nutritional value of a food by binding with calcium to form calcium oxalate. Bradbury et al., (1988) determined the amounts of total oxalate, soluble oxalate, calcium oxalate, and free calcium in taro corms and leaves, and found that the amount of free calcium is adequate for human nutrition. According to Standal et al., (1983).

All parts of most cultivars were known to contain calcium oxalate, which is destroyed by lengthy cooking. Boiling taro corm at 90°C for 30 minutes and steeping in water at 30°C for 24 hours can reduce the oxalate-salt content to 32.7% and 56.7% of its original content, respectively. Since taro is a staple food it is important to investigate whether the oxalate

content of taro leaves poses a risk factor and whether different methods of preparation and cooking can reduce the risk of absorbing excess soluble oxalates when consumed as part of the diet.

Wild taro is abundant, particularly in wet lands and is highly resistant to pest and diseases. The wild taro leaf has a high nutritive value, with 22.5-26.3% crude protein (Malavanh Chittavong *et al.*, 2008b). However, in common with other species of the Araceae family, calcium oxalate (an anti-nutritional factor), is found in all parts of the plant, causing irritation in the throat and mouth epithelium and indirectly affecting the digestibility. Research conducted by Esayas Ayele on effect of boiling temperature on anti-nutritional factors of taro showed that degrading the anti-nutritional factors by boiling so as to make the nutrients available; and making it safe to eat. Different boiling methods used in the study have varied effect in reducing the level of oxalate and phytate and enhanced the mineral content (Esayas Ayele *et al.*, 2009).

The soluble oxalate content can be reduced by soaking or cooking. Soaking for 18 h can reduce the soluble oxalate content by 26%. During the soaking treatment the insoluble oxalate (calcium oxalate) content of the leaves remained constant (mean 171 mg oxalate/100 g wet matter). Boiling the taro leaves resulted in a 36% loss of soluble oxalates, while the soluble oxalate content of baked tissue was very similar to the raw tissue. The mean insoluble oxalate content of the raw, boiled and baked tissue was 226 mg oxalate/100 g fresh matter. Overall, boiling the taro leaves was shown to be an effective way of reducing the soluble oxalate content of the tissue. Besides, the calcium oxalate content in taro leaf can also be reduced by sun-drying and ensiling, and Emmans G C 2008 reported that these processes can reduce calcium oxalate from 3.08 % in DM in the fresh leaf to 1.1 % after sun-drying and 0.11 % after storing.

2.6.3 Protease (Trypsin and Chymotrypsin) inhibitors

According to Bradbury *et al.*, (1998), acidity is caused by protease inhibitors (protein-degrading enzyme). Acridity is found in the corms and is experienced as a severe itching, stinging or burning sensation in the mouth and throat, followed by swelling or as a less severe irritation or itching of external skin (Osisioigu *et al.*, 1974). Acridity in taro is thought to be important as a natural defense against grazing animals (Bradbury *et al.*, 1988). Hollyer *et al.*, (1997) suggested several possible ways including wash with acidic ingredients or sodium bicarbonate can help to reduce acidity. The inhibitors constitute some 1- 4% of the total

crude protein in corms, and are absent or inactive in leaves. When corms are cooked, trypsin inhibitor activity increases at first, but is eventually lost. Twenty minutes of boiling is sufficient to remove trypsin activity and is also sufficient to remove the acidity in many taro cultivars.

2.6.4 Lectins

Plant lectins are an extremely heterogeneous group of proteins that have only one property in common, namely their ability to bind carbohydrates. Lectins may act as storage proteins that support new growth during the plant lifecycle, and also as biochemical defense molecules that anticipate attack by microorganisms or plant-eating organisms such as nematodes, insects, and other higher animals. Lectins are the most prominent proteins in the storage tissues of taro and other Araceae, and suggested that aroid lectins are storage proteins with the additional function of biochemical defense. Heating the lectin to 100°C for 20 minutes (a common length of time for cooking taro) eliminated its ability to reduce its inhibitor effect.

2.6.5 Alpha-amylase inhibitors

Alpha-amylases are enzymes that help animals and humans to digest starch. The enzymes are found in saliva and the small intestine, and can be inhibited by enzyme-specific inhibitors from many plants. The presence of alpha amylase inhibitors in taro corms can inactivate human salivary and pancreatic amylases (Soudy *et al.*, 2010). However alpha-amylase inhibitors are not very resistant to heat, losing activity *in vitro* after boiling for 30 minutes. If usual cooking practices do not deactivate these inhibitors, then they are reasonably tolerated by humans, and may be of little concern. This argument needs to be tested experimentally.

2.7 Processing of Taro in to different Products

The traditional ways to cook taro are roasting on stones or baking in a ground oven. More modern ways are boiling and steaming, or baking in an oven (Soudy *et al.*, 2010). Taro retains its food value if cooked whole and in its skin. It must be cooked thoroughly to prevent mouth and throat itching. Taro corms and leaves are usually consumed by humans after heat treatments, such as boiling, blanching, steaming, stewing, and frying and pressure cooking. These methods are found to be effective in improving digestibility, increasing nutrient bioavailability and also minimizing anti-nutritional factors and food-borne diseases.

Processing taro corm affects its proximate composition, mineral content, phytochemical components and Antinutrient (oxalate and phytate) contents. When taro corms processed into

powder and further decrease will occur when processed into taro noodles and cookies (Souidy et al., 2010). Therefore the combination of cooking time temperature program is necessary to preserves the nutrients and deactivates the anti-nutritional factors. On other hand cooking increases antioxidant activity, crude fat, crude protein and crude fiber contents cooking substantially can used in the management non communicable illness such as obesity, heart disease, blood pressure, Diabetes, cancer and gastrointestinal disorders because of the high fiber content (Souidy et al., 2010).

2.8 Drying methods suitable for Taro

The dried product quality and drying time are depends on the size of slices. Cutting large size produce into small pieces has been mentioned by authors as a way to accelerate drying due to increased surface area of the product and also avoids case hardening. For general food drying, it is commonly recommended to cut produce into thin pieces of not more than about 0.6-1.0 cm (1/4-3/8 inch).

Several drying methods are commercially available and the selection of the optimal method is determined by quality requirements, raw material characteristics, and economic factors. There are three types of drying processes: sun and solar drying, atmospheric dehydration including stationary or batch processes (kiln, tower and cabinet driers) and continuous processes (tunnel, continuous belt, belt-trough, fluidized-bed, explosion puffing, foam-mat, spray, drum, and microwave-heated driers) and sub atmospheric dehydration (vacuum shelf, vacuum belt, vacuum drum, and freeze driers) (Anon et al., 2001).

Sun drying is the oldest and easiest method of preservation based on reducing the moisture content of the Root and Tuber to a very low level. The concentration of soluble solids becomes relatively chemically stable. It is no longer a substrate for the growth of molds, yeasts and bacteria, thus preventing spoilage during storage.

Even today, the process is preferable because it lowers the cost of packaging, storing and transportation by reducing both the weight and volume of the final product (Mandhyan et al., 1988). As Njintang et al., (2007) studies sun drying had no effect on the pasting properties but it had more elastic paste and higher browning index of yam flour paste where as solar dryer had high quality of taro flour paste may be due to the slow rate of dehydration. Solar drying refers to methods of using the sun's energy for drying, but excludes open air sun drying. A solar dryer is an enclosed unit, to keep the food safe from damages from, birds,

insects and unexpected rainfall. According to Baker *et al.*, (1997) there are three types of solar dryers and they are classified according to the type of energy used. Solar natural dryers, Semi-artificial dryers and Solar-assisted dryers.

Solar natural drying is mainly used as substitutes for traditional open-air drying methods in areas where no other source of energy is available. In contrast to these traditional methods, however, losses and damage to the product caused by rain, dust, insects, birds and other animals, as well as the pollution from the atmosphere are avoided by the purpose built construction (i.e. cabinet and tent type arrangements).

Oven drying is the most widely used method to produce dried foods and agricultural products (Vega-Mercado *et al.*, 2001) due to the low investment and operating cost. However, a disadvantage of hot-air drying is that it takes a long time, even at high temperature, which in turn may cause serious damage to the product's quality attributes, such as flavor, color, texture, nutrient status and beneficial substances to health (Tsami *et al.*, 1999).

2.8.1 Taro flour

A major problem of taro is that the corms are susceptible to physical damage during harvesting and thus leading to high post harvest losses (Onwueme *et al.*, 1991; FAO *et al.*, 2006). To overcome these losses, the corms and cormels may be processed into flour (Onyeike *et al.*, 1995). According to Kwarteng *et al.*, (1994) taro flours stored much longer than the unprocessed tubers.

Several tuber products are accepted and preserved as flours after appropriate drying. Flours role in the feed and in food industry is very important (Nip *et al.*, 1997). Trying to produce them from new sources is necessary. Taro flour makes part of the new types of flour. Some recent studies establish a simple process to produce taro flour. In this process taro tuber are cooked in its skin, peeled, sun dried and ground through 500 μm sieves (Njintang *et al.*, 2003). The taro flour can then be used in other food formulations such as taro bread, taro cookies, baby food, pasta, or other products (Nip *et al.*, 1990). The corm's flour is also a good source of carbohydrate for diabetics and production of weaning food for infants and for those with gastrointestinal disorders (Onwueme *et al.*, 1978).

Pregelatinization is one of the physical methods used to modify starch. Taro starch gelatinization temperature is dependent on the variety as well as of the maturity at harvest

and is lower as the age increases, ranging from 63- 730C (Arnavid-Vinas et al., 1999). This method affects physicochemical and functional properties of flour significantly (Alam et al., 2009) due to starch granule disruption and such disrupted and pre gelatinized flour can absorb water.

Therefore it can create binder properties to obtain uniform matrix instantly when added to water (Doubliel et al., 1986). The solubility of modified starch from taro was studied by Alam et al., (2009) and found that heat moisture treated starch is more soluble than raw starch. In addition, it was reported that pregelatinized product have higher overall acceptance (Chinnajarn et al., 2006).

2.8.2 Taro chips

Chips made from the bottom of the corm are rated better in appearance than those made from the top part. This is because the bottom part is dryer (around 5 percent greater dry matter content than the top part). Research also indicates that the level of nitrogen fertilizer significantly affects corm dry matter. The more N, the lower the dry matter, and as little as 5 percent differences in fertilizer application can affect chip quality and color (James Hollye et al., 2000).

Taro nutritional importance and related information on its cultivation, post-harvest management, processing possibilities in order to prolong the shelf life of fresh taro corm. Moreover, the important information's are the nutritional, ant-nutritional components of Taro. Taro is used as a staple food or subsistence food by millions of people in the developing countries in Asia, Africa and Central America and can be consumed as both a staple food and vegetable, and processed as a food ingredient, animal feed. The corms of taro are used as vegetable and considered as a rich source of carbohydrates, proteins, minerals and vitamins and accredited to have medicinal values and are used to reduce tuberculosis, ulcers, pulmonary congestion, fungal infection and reducing body temperature in a feverish patient and others In Ethiopia, root crops are grown widely in the south region and among these crops; taro is one of the important food source as well as income source to the farmer. In the southern part of the country, it has a great potential to supply high quality food and one of the cheapest source of energy.

Nutritionally, taro contains more than twice the carbohydrate content of potatoes and yield 135 kcals per 100 g. Taro contains about 11% protein on a dry weight basis. This is more

than yam, cassava or sweet potato also stated that the protein content of taro is higher than the other root crops. It contains 85-87% starch on dry matter basis with small granules and other nutrients such as minerals, Vitamin C, thiamin, riboflavin and niacin better than cereals. Taro leaves, like higher plants, is rich in protein. The high protein content of the leaves favorably complements the high carbohydrate content of the tubers. Underutilized crops such as taro have much importance in ensuring food security, in earning foreign currency as being a cash crop and also as a means for rural development. Most rural peoples suffer from malnutrition not because of the economic status but because of inability to utilize the available nutritious underutilized crops such as taro to meet their daily requirements. To meet the nutritional demand there must be a need to see the economic and nutritional impact of indigenous fresh underutilized crops such as taro for its production and consumption in rural communities. Therefore it can be goodness for malnutrition and food insecurity for rural peoples as rural food sources.

2.9 Calcium Oxalate Reduction in Taro (*Colocasia esculenta*) Corm Chips during Treatments Using Baking Soda Solution

An effort on the reduction of calcium oxalate content from Taro corms through soaking and boiling of Taro corm chips in baking soda solution was carried out. Soaking and boiling of Taro corm chips in baking soda solution was still unable to reduce the calcium oxalate content to safe level. A mathematical model, which involves dissolution, reaction and decomposition mechanisms was developed and well verified its accuracy by comparing with experimental data. From the technical and economics point of views, a relatively good condition to reduce calcium oxalate content was by soaking Taro corm chips in 10 % w/w baking soda solution at ratio 1:4 (w/v) for 10 hours at ambient temperature followed by boiling at 98°C for 60 minutes to obtain Taro flour with similar functional properties of American wheat flour (Andri Cahyo Kumoro *et al.*, 2014).

The chemical compositions of *Colocasia esculenta* corm and cormel (a small corm growing at the side of a mature corm), considered on dry weight basis, are not different. Hence, the choice of either corm or cormel for any preparation may not be necessary. Blanching and sulphating treatments did not affect the proximate compositions of the flours but affected the ascorbic acid, anthocyanin and oxalic acid contents. Blanching increased the water and oil absorption capacities, bulk density and aesthetic value of the flour. Sulphating and particle size classification only improved the aesthetic value of the flour. Neither treatment nor

particle size classification affected the acceptability of the soups prepared from the cocoyam flours. The increase in aesthetic value by the treatment and particle size classification may be a marketing tool. The effect of the treatments and particle size classification on other applications of the flour should be studied (Greenwell *et al.*, 1947).

2.10 Effect of Fermentation on Physicochemical Properties and Oxalate Content of Cocoyam (*Colocasia esculenta*) Flour

Fermentation was affected the calcium oxalate and some physicochemical properties of Taro flour. Calcium oxalate was reduced significantly; the greatest reduction was observed in the 48 hour fermentation, which reduced the oxalate level by approximately 65%. Water absorption capacity of the fermented Taro was increased markedly and viscosity also was reduced. The high setback value of fermented Taro flour makes it suitable for jelly foods. Further work was on the effect of longer fermentation period (72-96 hours), as well as the microorganism associated with the fermentation and the development of starter culture to ferment Taro was to see changes on the oxalate content and other physicochemical properties of Taro flour (Onayemi *et al.*, 1987).

2.11 Changes during before and after cooking of Taro (*Colocasia esculenta*)

The main compounds that limit the digestion and absorption of nutrients and result in reduced bioavailability of nutrients and flatulence production are Anti-nutrients (Brune *et al.*, 1989). Most anti-nutrients can be partially eliminated technological processes like cooking so that their acute toxicity becomes mild (Polomy *et al.*, 1997; Adeparusi *et al.*, 2001; West *et al.*, 2007). However, the possible health risk to those consuming food with high quantities of residual anti-nutrients cannot be ruled out. Oscarsson *et al.*, (2007) surmised (guessed) that Taro (*Colocasia esculenta*) had its origins in the tropics between India and Indonesia and the Food and Agricultural Organization (FAO *et al.*, 1992, cited in Oscarsson *et al.*, (2007) commented that this plant had been grown in the South Pacific for hundreds of years.

According to Bradbury *et al.*, (1998), many Taro (*Colocasia esculenta*) cultivars have a sharp, pungent taste and should not be eaten raw, because they can cause swelling of lips, mouth and throat if eaten unprocessed. This causticity is caused by closely-packed, needle-like, calcium oxalate crystals, which can penetrate soft skin (Bradbury *et al.*, 1998). Thereafter, an irritant, probably a protease, present on the sheath like bundle of needles (raphides) can cause discomfort in the tissue (Bradbury *et al.*, 1998; Paul *et al.*, 1999). Both the tubers and the leaves can give this reaction (FAO *et al.*, 1992) but this effect is reduced by cooking

(Bradbury *et al.*, 1998). The tubers have to be thickly peeled and cooked over a long period, for comfortable consumption (Sakai *et al.*, 1979; Crabtree *et al.*, 1982). Cooking, a process which takes longer than blanching increased the losses of total oxalates. Compared with blanching, Cooking resulted in significant decrease in soluble oxalate content in Taro (*Colocasia esculenta*). Mosha *et al.*, (1995) observed that prolonged thermal processing increased losses in oxalates, as was also found in the present study. Onayemi *et al.*, (1987) identified the following constituents in Taro (*Colocasia esculenta*), digestible starch, high-quality protein, essential amino acids, vitamin C, thiamine, riboflavin and niacin.

2.12 The effect of temperature on the calcium oxalate concentration in Taro corm chips

Literature study has revealed that the solubility of calcium oxalate in water increases with increasing temperature (Goodenough *et al.*, 1973) and that the decomposition reaction of calcium oxalate crystals into calcium oxide also occurs rapidly at high temperatures (Schempf *et al.*, 1965). As a result, the final calcium oxalate content in the taro corm cubes was lowest for taro corm chips boiled in 60% concentration of Tamarind pulp at 100°C for 60 minutes. Again, these results suggest that boiling of taro corm cubes in 60 % concentration of Tamarind pulp at 100°C for 60 minutes is sufficient to reduce the calcium oxalate content to safe level.

2.13 Preparation of sugar treated cubes from other food sources

Bottle gourd cubes (Tutti Fruity) was prepared by peeling, washing, making halves of bottle gourds and then de-cored and cut into pieces of average length of 5.0 ± 1.0 cm slices, breadth 2.0 ± 0.5 cm and thickness of 2.0 ± 0.5 cm. The raw pieces of bottle gourd were blanched at 90°C for 2mins and drained. After draining the pieces were then cut into 0.8 ± 0.2 cm³ sized cubes and then the bottle gourd cubes were taken in a pre-washed, sanitized, clean, pre-weighed stainless steel vessel. The water and sugar for making sugar syrup was based on the weight of the bottle gourd cubes i.e., 70% by weight of the cubes and salt added was 0.1% by weight of bottle gourd cubes and concentration was done till different level of degree Brix of sugar syrup (using digital Refractometer) was achieved. The different sugar syrup concentration was studied are from 60, 65, 70 and 75° Brix by heating on medium flame. It was observed that cooking to final concentration up to 60 and 65°Brix resulted in final bottle gourd cubes having uncooked, unpleasant, predominant raw bottle gourd flavour, less sweet and less acceptable in terms of sensory evaluation. So cooking to concentration up to 70° Brix was resulted in final quality cubes having very pleasant, clean, caramelized, sweet

flavour and properly cooked firm texture was seen. The final concentration of sugar syrup used was 70° Brix for the preparation of bottle gourd cubes. It was reported in literature that treating bottle gourd cubes with calcium chloride solution for preparation of Tutti Fruity from bottle gourd resulted in improved firmness of cubes. Therefore in the literature, effect of treating blanched cubes by addition of calcium chloride on body and texture of processed bottle gourd cubes were evaluated. After blanching the cubes were dipped in 1% calcium chloride solution for 3 hours. The cubes were then drained, mixed with equal quantity of 50° Brix sugar syrup and were cooked by heating on a direct flame to till the concentration of sugar syrup reached to 70° Brix. It was observed in that, CaCl₂ treated bottle gourd cubes had slight off flavour. But the shape and colour were acceptable. The Control sample had no good shape, flavour and also colour retention, uniform texture and firmness like Tutti Fruity and there was no perceptible difference was found in body and firmness of the prepared samples. There was no improvement caused on texture or firmness of bottle gourd cubes with CaCl₂ treatment, so the treatment was not used for the preparation of bottle gourd cubes (Babar *et al.*, 1996, Barot Amit *et al.*, 2014).

2.14 Physicochemical Properties

2.14.1 Effect of Pre-treatment and Storage Condition on the Physicochemical Properties of Taro (*Colocasia esculenta* [L.] Schott) Flour

Reducing sugars and water activity were affected by the pretreatments. Blanched samples showed highest reducing sugar content whereas samples treated with 2% sodium chloride solution had the lowest. The highest water activity was recorded in 2% sodium chloride pretreatments. The least water activity was observed for control samples.

Reducing sugars and water activity were affected by the pretreatments and blanched samples had the greatest reducing sugar content whereas samples treated with 2% sodium chloride solution had the least. The highest water activity was recorded in 2% sodium chloride solution compared to the other pretreatments.

2.14.2 Effect of boiling time on chemical composition and physico-functional properties of flours from Taro (*Colocasia esculenta*) corm

Taro (*Colocasia esculenta*) corm was subjected to different boiling times and the changes in chemical composition and physico-functional properties were investigated using standard method. The change in boiling time led to a significant ($P < 0.05$) reduction in the moisture, reducing sugars, total sugars, crude fat, crude fiber, total phenolic compound contents and

iodine affinity of starch, whereas the total carbohydrate content, water absorption capacity, water solubility index, paste clarity and foam capacity increased significantly ($p < 0.05$). The crude protein and total ash contents of the flours from taro corm were not affected significantly ($p < 0.05$) by the change in boiling time. Taro corm flours exhibited highest total carbohydrate, crude fiber, total ash contents, water absorption capacity, iodine affinity of starch and lowest crude protein and fat contents, foaming capacity and water solubility index.

This report shows that the boiling time has significant ($p < 0.05$) effect on the moisture, reducing sugars, total sugars, crude fat, crude fiber, total phenolic compound, total carbohydrate contents, iodine affinity of starch, water absorption capacity, water solubility index, paste clarity and foam capacity of flour from the Ivorian taro (*Colocasia esculenta*) corm. The crude protein and total ash contents were not affected significantly ($p < 0.05$) by the change in boiling time. The taro corm flour is a good source of carbohydrate, crude fiber and total ash going by the chemical score and therefore should be appreciated as a food security crop. The high WAC of taro flour makes it a good body providing agent and can thus be used as a thickener or gelling agent in various food products. Based on these results, taro flour has a good potential to be used in food industry either for development of new food products.

2.14.3 Effect of processing method on the proximate composition, mineral content and antinutritional factors of Taro (*Colocasia esculenta* [L.] Schott)

Boiling had shown the highest reduction of oxalates in taro. Accordingly, boiling of taro had reduced the oxalate contents by 70.9% for Boloso I. The results obtained in this study agreed with that of Iwuoha and Kalu who reported 65.7-82.1% reduction of oxalates by boiling (Iwuoha *et al.*, 1994). The reduction of oxalates during boiling may be due to its solubility in boiling water. As indicated by Albihn and Savage boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalates into cooking water (Albihn *et al.*, 2001).

2.14.4 Studies on Effects of Processing on Oxalate Content in Agricultural Produce (*Colocasia esculenta*, *Prunus dulcis*, *Glycine max*)

Maximum reduction in the content of oxalate of up to 50% was noticed in the studied samples after subjecting for processing. For taro (*Colocasia esculenta*) the pressure cooking for 7min. and blanching at temperature 65°C for 1hr were preferred (Sasanka Sekhar Dash *et al.*, 2011).

The reduction in oxalate content may be due to the different treatments done to raw taro prior to drying like washing, peeling, dicing, soaking overnight and blanching as well as the boiling of noodles and baking done in making cookies. Washing according to the studies of Huang *et al.* (Huang *et al.*, 2007) reduced the concentration of oxalate by 9.2%, while Akpan and Umoh (Akpan *et al.*, 2004) stated in their study that the peel of tubers contains more oxalate than the peeled tubers. Buntha *et al.*, (2008) also reported that the acidity of high oxalate cultivars of taro can be reduced by peeling, grating, soaking and fermentation during processing. Thus, dicing of the tubers makes the tissues finer and smaller resulting in greater surface area exposed to soaking medium so that leaching process is faster. Huang *et al.*, (2010) also found out in their studies that soaking reduced the concentration of oxalates by 23.5% and cooking by 56.7% (Huang *et al.*, 2007). Shanthakumari *et al.*, (2008) further confirmed that the decrease in the anti-nutritional factors like oxalates during soaking may be due to leaching out of these substances in soaking medium. Boiling may cause considerable cell rupture and facilitate leakage of soluble oxalate into cooking water (Albihn *et al.*, 2001).

2.14.5 Physical and Chemical characteristics of Taro [*Colocasia esculenta* (L.) Schott] Corms and Processing to Chips and Puree

This study was carried out to establish some physical properties and proximate chemical compositions of taro corms collected from Anamur and Bozyaz in Çel province, Turkey. A total of two taro corms from different sources were evaluated for pH, dry matter, crude protein, crude cellulose unrefined oil, starch, invert sugar, total sugar, ash, Ca, Mg and K. The samples collected from Anamur and Bozyaz differed in some parameters. Taro corms were rich in starch, magnesium and potassium. Sensory analysis of the products showed no difference between the samples, and taro purees were less liked while French fries were more preferred when compared with those made with potatoes. Taro and its products were recommended as a novel crop and a valuable food source.

It can be recommended for low-calorie diets because it is rich in nutrients, protein, minerals and vitamins. It is also a positive factor that the pH is close to the neutral.

3. MATERIALS AND METHODS

3.1 Collection and preparation of Taro corm

The Taro (*Colocasia esculenta*) was purchased from local Supermarket at Masabtank, Hyderabad Telangana state. The Taro is cleaned by running tap water to remove dirt and

extraneous matter and then peeled by using normal kitchen peeler and then cut into 0.6 ± 0.2 cm³ size cubes.

3.2 Preparation of Tutti Fruity from Taro corms

Preparation of the Tutti Fruity from the Taro is carried out by the method described by Barot Amit *et al.*, 2014 with some modifications. 100gms of chopped Taro cubes were taken in pre-washed, sanitized, clean and pre-weighed stainless steel vessel and undergone different treatments at different concentrations with tamarind pulp and salt solution.

Samples(1a,1b,1c,1d,1e,1f,1g,1h,1i) blanched at 90°C for 3mins with Tamarind pulp at concentrations of 5%(1a), 10%(1b), 15%(1c), 20%(1d), 25%(1e), 30%(1f), 40%(1g), 50%(1h), 60%(1i) and sample(1j) blanched in water at 90°C for 3mins. Samples (2a,2b,2c,2d) boiled at 100°C for 60mins with Tamarind pulp at concentrations of 30%(2a), 40%(2b), 50%(2c), 60%(2d) and Sample(2e) boiled in Water at 100°C for 60mins. Samples (3a,3b) boiled at 100°C for 30mins with Salt solution at concentrations of 2.5%(3a), 5%(3b) and samples(3c,3d) boiled at 100°C for 60mins with Salt solution at concentrations of 2.5%(3c), 5%(3d). Each Sample was composed of 100gms of Taro cubes. Specific amounts of Tamarind and Salt was suspended in water and mixed.

Blanching of Taro cubes is to prevent enzymatic browning and to determine the presence of itching when treated with Tamarind pulp at different concentrations as well as boiling with water, salt solution and tamarind pulp. After every treatment, Taro cubes are removed from the heat and let it stand in the stainless steel vessel for 5mins to cool the water or solution to 60°C, drained the cubes and then dipped in cold water to remove hindrance of tamarind and salt stick on the surface of the cubes. The cubes are then immersed in sugar syrup made from water and sugar with 70% by weight of the cubes. The sugar syrup concentration made up to 75° Brix from an initial of 60° Brix by using digital Refractometer, the heating is done on low medium flame to get desired degree Brix. After the final degree Brix, the sugar syrup removed from the heat and cooled. To this syrup 0.5gms red colour (1ppm as per FSSAI act) added and mixed. The sugar syrup with Taro cubes is kept for around 12-24 hours so that the sugar syrup totally absorbed by the cubes, after that Taro cubes drained from the syrup and spread over a Tray and dried at 60°C in a tray drier for 10-20 minutes, cooled and packed in polythene bag.

Table 3: Step1 (Blanching in Tamarind pulp and Water at 90°C for 3mins).

Sample 1	Treated with	Concentration	Method applied
a	Tamarind Pulp	5%	Blanching at 90°C for 3mins
b	Tamarind Pulp	10%	Blanching at 90°C for 3mins
c	Tamarind Pulp	15%	Blanching at 90°C for 3mins
d	Tamarind Pulp	20%	Blanching at 90°C for 3mins
e	Tamarind Pulp	25%	Blanching at 90°C for 3mins
f	Tamarind Pulp	30%	Blanching at 90°C for 3mins
g	Tamarind Pulp	40%	Blanching at 90°C for 3mins
h	Tamarind Pulp	50%	Blanching at 90°C for 3mins
i	Tamarind Pulp	60%	Blanching at 90°C for 3mins
j	Water	100%	Blanching at 90°C for 3mins

Table 4: Step2 (Boiling in Tamarind pulp and Water at 100°C for 60mins).

Sample 2	Treated with	Concentration	Method applied
a	Tamarind Pulp	30%	Boiling at 100°C for 60mins
b	Tamarind Pulp	40%	Boiling at 100°C for 60mins
c	Tamarind Pulp	50%	Boiling at 100°C for 60mins
d	Tamarind Pulp	60%	Boiling at 100°C for 60mins
e	Water	100%	Boiling at 100°C for 60mins

Table 5: Step3 (Boiling in Salt solution at 100°C for 30mins and 60mins).

Sample 3	Treated with	Concentration	Method applied
a	Salt	2.5%	Boiling at 100°C for 30mins
b	Salt	5%	Boiling at 100°C for 30mins
c	Salt	2.5%	Boiling at 100°C for 60mins
d	Salt	5%	Boiling at 100°C for 60mins

3.3 The process flow chart as follows

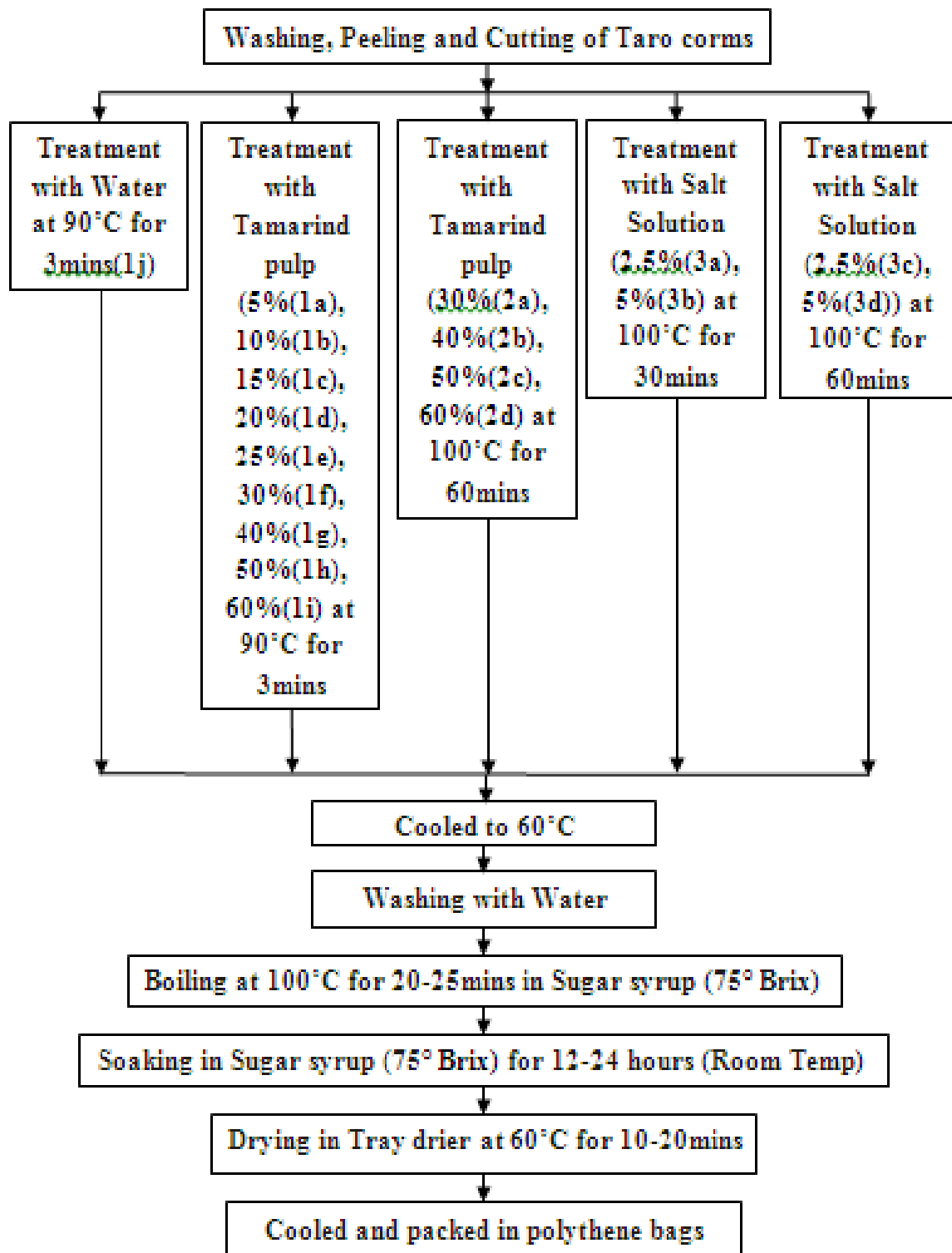




Fig 2: Step 1-Blanching in Tamarind Pulp at 90°C for 3mins.

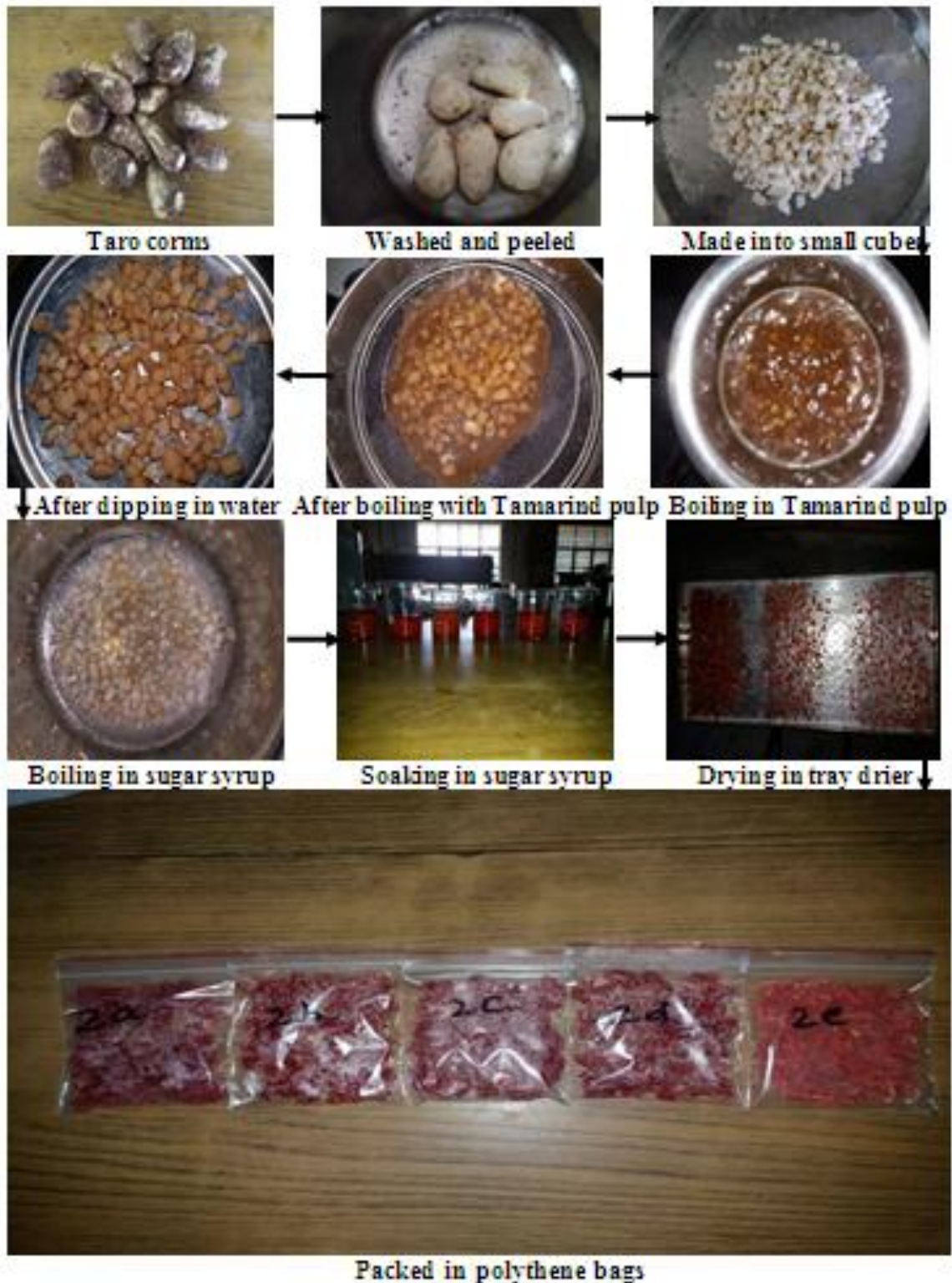


Fig 3: Step 2-Boiling in Tamarind Pulp at 100°C for 60mins.

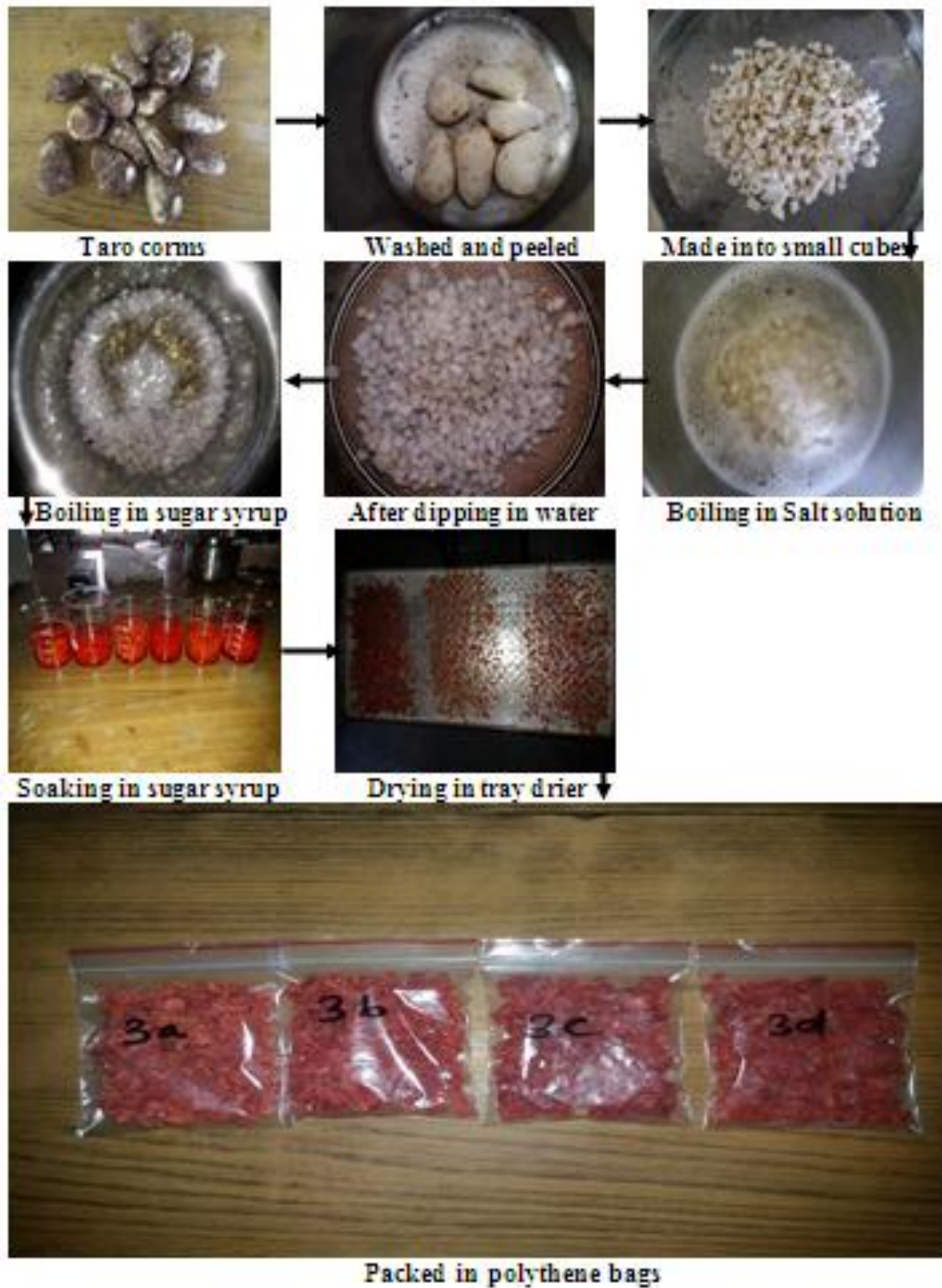


Fig 4: Step 3-Boiling in Salt solution at 100°C for 30mins and 60mins.

3.5 Sensory evaluation

Samples were served in the sealed and closely packed polythene pouches. The pouches were labelled with alphabetical order for each sample codes. Panelists were provided with evaluation card and coded samples. The order of presentation of the samples along with control sample was randomized across subjects. Subjects judged a maximum of 10 samples in first session, in second session 5 samples and in third session 4 samples were presented. The sensory panel n=30 (untrained) was composed of 25 under graduate students and 5 non teaching members working in the institution.

Each participant evaluated all 20 Tutti Fruity samples (1a to 1j, 2a to 2e and 3a to 3d) including Control sample to rate the sensory attributes of flavour, texture, taste, appearance, presence of itching and overall acceptability using a 9 - point hedonic scale suggested by Ranganna *et al.*,(2001): 9-like extremely, 8-like Very Much, 7-Like moderately, 6-Like slightly, 5-Neither like or dislike, 4-Dislike Slightly, 3-Dislike Moderately, 2-Dislike Very Much, 1-Dislike Extremely. Groups of 30 panellists were used in every instant for the sensory evaluation exercise. Necessary precautions were taken to prevent carryover of presence of itching during the test by ensuring that panellists rinsed their mouth properly with clean drinking water after evaluating each Tutti Fruity.



Fig 5: Control sample.



Fig 6: Samples of Step1 (Blanching in Tamarind pulp And Water at 90°C for 3mins).



Fig 7: Samples of Step2 (Boiling in Tamarind pulp Salt solution at and Water at 100°C for 60mins).



Fig 8: Samples of Step3 (Boiling in 100°C for 30mins and 60mins).

3.6 Ranking test using Fiducial limits

Experimental data were analyzed by ranking method and fiducial limits test was used to compare the mean of the control sample with all the samples. Comparisons among samples were analyzed using the ranking method and the significant differences among samples means were determined using fiducial limits at $p \leq 0.05$. Fiducial limits test was used for mean separation and the results were expressed as mean \pm standard deviation.

RESULTS AND DISCUSSION

Table 6: Sensory evaluation of Taro Tutti Fruity (Mean \pm Standard deviation).

S. No	Samples	Flavour	Texture	Taste	Appearance	Overall Acceptability
1	Control	1.5 \pm 0.5	1.4 \pm 0.5	1.4 \pm 0.5	1.43 \pm 0.5	1.4 \pm 0.5
2	1a	4.3 \pm 1.34	3.97 \pm 1.15	3.83 \pm 1.11	4.1 \pm 1.24	3.93 \pm 1.37
3	1b	4.1 \pm 1.32	4.37 \pm 1.32	3.57 \pm 1.38	4.1 \pm 1.24	4.23 \pm 1.1
4	1c	4.23 \pm 1.04	4.83 \pm 0.95	4.2 \pm 1.4	4.57 \pm 1	4.73 \pm 1.52
5	1d	4.87 \pm 1.04	4.6 \pm 1	4.17 \pm 1.53	4.13 \pm 1.33	4.47 \pm 1.3
6	1e	4.17 \pm 1.6	5.77 \pm 1.7	4.03 \pm 1.32	4.73 \pm 1.31	4.37 \pm 1.2
7	1f	4.27 \pm 1.08	5.47 \pm 2.11	4.17 \pm 1.26	4.7 \pm 1.44	5.2 \pm 1.6
8	1g	4.33 \pm 1.12	5.83 \pm 1.7	4.03 \pm 1.27	4.9 \pm 1.42	4.97 \pm 1.54
9	1h	3.93 \pm 0.8	4.33 \pm 1.5	3.73 \pm 1.3	4.43 \pm 0.93	4.6 \pm 1.3
10	1i	1.9 \pm 0.71	1.77 \pm 0.72	1.9 \pm 0.75	1.83 \pm 0.7	1.67 \pm 0.7
11	1j	3.97 \pm 1.21	4.4 \pm 1.19	4 \pm 0.8	3.47 \pm 1	4.67 \pm 1.3
12	2a	2.7 \pm 0.74	3.4 \pm 1.1	1.73 \pm 0.94	2.67 \pm 0.92	3.37 \pm 1.03
13	2b	2.43 \pm 0.9	2.13 \pm 0.9	1.83 \pm 0.8	2.8 \pm 1	3.6 \pm 1.03
14	2c	2.37 \pm 0.8	2.83 \pm 0.91	2.73 \pm 0.9	3.37 \pm 1.12	3.17 \pm 0.94
15	2d	1.8 \pm 0.61	1.7 \pm 0.7	1.83 \pm 0.7	2.17 \pm 0.65	1.57 \pm 0.6
16	2e	4.1 \pm 0.9	4.4 \pm 1.16	4.03 \pm 0.71	3.73 \pm 0.8	1.63 \pm 0.71
17	3a	8.6 \pm 0.81	4.93 \pm 1.4	8.83 \pm 0.74	4.6 \pm 1	8.13 \pm 1.43
18	3b	8.63 \pm 0.8	4.77 \pm 2.2	8.83 \pm 0.74	4.87 \pm 1.13	7.9 \pm 1.42
19	3c	8.73 \pm 0.94	4.6 \pm 2.04	8.8 \pm 0.8	4.87 \pm 1.75	7.97 \pm 1.42
20	3d	8.67 \pm 1.12	4.83 \pm 1.05	8.73 \pm 0.94	4.67 \pm 1.06	7.6 \pm 1.92

1a-5%,1b-10%,1c-15%,1d-20%,1e-25%,1f-30%,1g-40%,1h-50%,1i-60% blanched at 90°C for 3mins with Tamarind pulp ,1j blanched in water at 90°C for 3mins;2a-30%, 2b-40%, 2c-50%, 2d-60% boiled at 100°C for 60mins with Tamarind pulp,2e boiled in Water at 100°C for 60mins; 3a-2.5%, 3b-5% boiled at 100°C for 30mins with Salt solution, 3c-2.5%, 3d-5% boiled at 100°C for 60mins with Salt solution.

Table 7: Presence of itching yes/no of all samples by Sensory evaluation data.

S. No	Sample	Sum of presence of itching yes/no
1	Control	30no
2	1a	3no-27yes
3	1b	21no-9yes
4	1c	12no-18yes
5	1d	7no-23yes
6	1e	18no-12yes
7	1f	10no-20yes
8	1g	10no-20yes
9	1h	6no-24yes
10	1i	25no-5yes
11	1j	30yes
12	2a	30yes

13	2b	18no-12yes
14	2c	8no-22yes
15	2d	26no-4yes
16	2e	23no-7yes
17	3a	30yes
18	3b	30yes
19	3c	1no-29yes
20	3d	30yes

Table 8: Mean value of all samples in terms of Overall acceptability parameter by Sensory evaluation data.

S. No	Sample	Mean
1	Control	1.37
2	1a	3.93
3	1b	4.23
4	1c	4.73
5	1d	4.47
6	1e	4.37
7	1f	5.2
8	1g	4.97
9	1h	4.6
10	1i	1.67
11	1j	4.67
12	2a	3.37
13	2b	3.6
14	2c	3.17
15	2d	1.57
16	2e	1.63
17	3a	8.13
18	3b	7.9
19	3c	7.97
20	3d	7.6

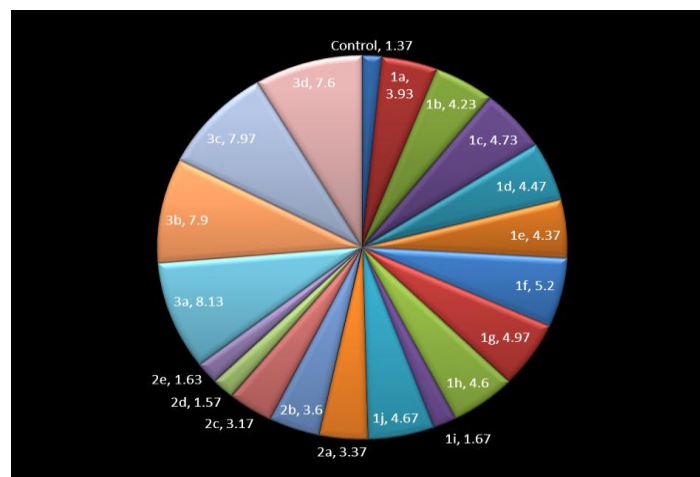


Fig 9: Pie chart for mean value of all samples in terms of Overall acceptability parameter by Sensory evaluation data.

Table 9: Overall Rank of all samples in terms of Overall acceptability by Sensory evaluation data.

S. No	Sample	Overall Score	Rank
1	Control	40	1
2	1a	110	8
3	1b	119	9
4	1c	133	13
5	1d	126	11
6	1e	122	10
7	1f	147	16
8	1g	141	15
9	1h	130	12
10	1i	49	4
11	1j	134	14
12	2a	98	6
13	2b	105	7
14	2c	92	5
15	2d	46	2
16	2e	48	3
17	3a	214	20
18	3b	207	18
19	3c	209	19
20	3d	198	17

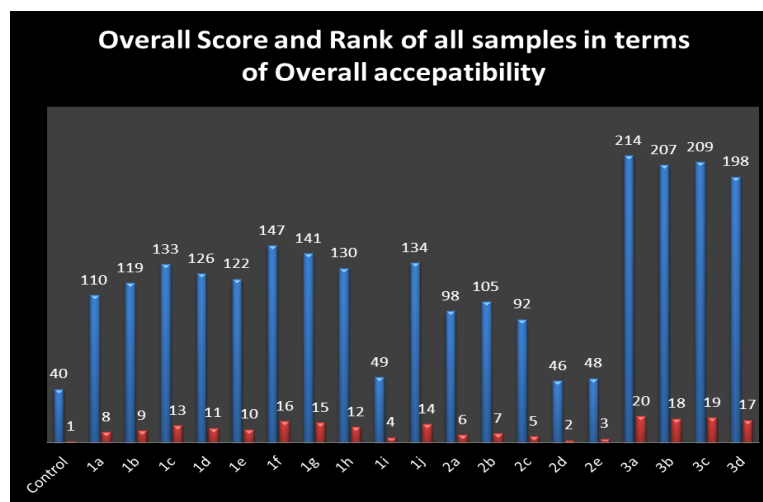


Fig 10: Bar graph for Overall Rank of all samples in terms of Overall acceptability parameter by Sensory evaluation data.

From Table-6, After Control sample, Sample2d (Boiling at 100°C for 60mins in 60% Tamarind pulp) found no itching as maximum panelists feel no itching and reduction of Calcium oxalate crystals were more in sample 2d, out of 30 panelists 26 panel members found no itching and 4 members found itching after consumption of sample 2d.

From Table-8, The fiducial limits of control sample are used as significance at 1% and at 5% levels which after determining fiducial limits of the Control sample at 1% ($p < 0.01$) and 5% ($p < 0.05$) levels sample 2d mean value falls in the fiducial limits of Control sample at 1% ($p < 0.01$) level, so Sample2d (Boiling at 100°C for 60mins in 60% Tamarind pulp) is significantly superior to all samples and sample1i (Blanched at 90°C for 3mins in 60% Tamarind pulp) and sample2e (Boiling in Water at 100°C for 60mins) are significantly inferior to the sample2d at 1% level ($p < 0.01$).

From Table-6, Mean value of control sample followed by sample2d (Boiling at 100°C for 60mins in 60% Tamarind pulp) has least mean value in terms of Overall acceptability when compared to all samples, so sample2d is significantly superior to all samples.

In Table-9, After Rank of the control sample, sample2d (Boiling at 100°C for 60mins in 60% Tamarind pulp) got the Rank 1 when compared to all samples in terms of Overall acceptability, so sample 2d is significantly superior to all samples.

Tutti Fruity made from sample 2d (60% concentration of Tamarind pulp boiled at 100°C for 60mins) was having excellent organoleptic properties in terms of colour, flavour, texture, taste and appearance and was similar to that of papaya Tutti Fruity. Maximum panellist feels no itching after consumption of sample 2d as itching (Calcium oxalate crystals) was reduced in the sample 2d due to prolonged boiling followed by Tutti Fruity made from sample 1i (60% concentration of Tamarind pulp blanched at 90°C for 3mins) and sample 2d followed by sample 1i are acceptable by panel members with respect to maximum reduction of itching. So after the control sample and out of the samples have tried Sample 2d is best followed by Sample 1i with respect to acceptability, overall acceptability, Ranking and even itching.

CONCLUSIONS

1. The need to improve the value of roots especially those are underutilised, like Taro is timely in recognition that local roots are the basis for the diets. Hence the need to explore various options for extending the Taro uses.
2. Product development is the key to increase root crop consumption in general and Taro in particular. Taro is a particularly suitable raw material for product development since it is bland and essentially without color.
3. In the light of the above, the Taro corm processed with different methods was determined in order to ascertain its suitability and acceptability in terms of itching and making Tutti

Fruity. The overall acceptability of Taro Tutti Fruity is compared with the papaya Tutti Fruity.

4. The process which applied on Sample 2d (Boiling of Taro corms in 60% concentration of Tamarind pulp at 100°C for 60mins) reduces the itching by removing the raphides (needle like crystals of calcium oxalate) in the other methods which applied are not effecting the calcium oxalate crystals and unable to reduce itching or calcium oxalate crystals and all panellists feels itching and are non usable methods whereas method applied in sample 2d is able to reduce more calcium oxalate crystals or itching so panellists feels no itching and it is more acceptable followed by sample 1i. Therefore it can be concluded that the raphides of calcium oxalate which leads to itching can be reduced by prolonged boiling of Taro corms with 60% concentration of tamarind pulp for 60mins at 100°C and is the most appropriate time, temperature and concentration to reduce itching after consumption of Taro corms. So by applying Tamarind pulp 60% concentration we can reduce more itching or calcium oxalate crystals from Taro and Taro can be converted to other products like Tutti Fruity because panellists feel no itching and accepted this product so it can be utilized in different food products.
5. Hence the use of Taro Tutti Fruity should be further explored and used in Cakes, Bun, Muffins, Cookies, Bread, and Custard & Ice-Cream. This will extend as well as increase the utilisation options for this underutilised tuber beyond its current basic use. This diversification in the value chain for Taro can also become an increased source of income for Taro farmers and food processors.

ACKNOWLEDGEMENT

This dissertation work has been kept on track and been seen through to completion with the support and encouragement of numerous people. I would like to thank all those people who contributed in many ways to the success of this study and made it an unforgettable experience for me.

I sincerely thank Prof. Dr. R. Shyam Sunder, Principal and Head of the Department of Technology, University College of Technology (A), Osmania University, for providing me the opportunity to undertake this work. I am also grateful to Prof. Dr. E. Nagabhushan, Dean, University College of Technology (A), Osmania University, Hyderabad.

At this moment of accomplishment first of all I pay homage to Sri Vellenki Bhaskar, Assistant Professor (C), Department of Technology (Food Technology) and to my guides Sri

D. Kodandaram Reddy, Assistant Professor (C) (Food Technology) and Prof. Dr. Kavitha Waghray, Former Head of Food Technology, University College of Technology (A), Osmania University, Hyderabad for providing necessary infrastructure and resources to accomplish my work. I am very much thankful to them for picking me up as a student at the critical stage of my dissertation work. This work would not have been possible without their guidance, support and encouragement. Under their guidance I successfully overcame many difficulties and learned a lot. Despite of their busy schedule, they used to review my work progress, gave their valuable suggestions and made correction.

I express my sincere gratitude to Sri Srinivas Maloo, Chairman BOS in Food Technology, Associate Professor, Program Coordinator of Food Technology and Mr. V. Bhaskar, Assistant Professor (C) (Food Technology), University College of Technology (A), Osmania University, Hyderabad for permitting me to uptake this project work.

I am also extremely indebted to Prof. Dr. Jyoti Kiran Singh, Renuka Pillai, Assistant Professor (C) (Food Technology), University College of Technology (A), Osmania University, Hyderabad.

I sincerely thank Sri Anjaneyalu sir, Lab assistant, Food Technology, University College of Technology (A), Osmania University, Hyderabad, for providing me the opportunity and facilities to undertake this work.

I would like to extend my appreciation to Mrs. Ragini mam, PhD Scholar for her support and help during the course of my work. I am grateful to all staff members for their cooperation. I am indebted to all the staff members of University College of Technology (A), Osmania University, Hyderabad for their immense support and cooperation.

I am indebted to my family: my parents for giving birth to me at the first place and supporting me spiritually throughout my life and my brother for his unconditional love, inspiration and encouragement.

BIBLIORAPHY

1. Adane T, Shimelis A, Negussie R, Tilahun b , Gulilat D effect of processing method on the proximate composition, mineral content and ant-nutritional factors of taro (*Colocasia esculenta*, l.) grown in Ethiopia, 2013.

2. Adeparusi E.O. Effect of processing on the nutrients and anti-nutrients of lima bean (*Phaseolus lunatus* L.) flour. *NahrungIFood*, 2001; 45: 94-96.
3. Akpan EJ, Umoh IB Effect of Heat and Tetracycline Treatments on the Food Quality and Acridity Factors in Cocoyam [*Xanthosoma sagittifolium* (L) Schott]. *Pak J Nutr*, 2004; 3: 240-243.
4. Alam, F. and A. Hasnain, Studies on and solubility of modified starch from taro (*Colocasia esculenta*) effect of pH and temperature. *Agricultural Conspectus Scintificus*, 2009; 74(1): 45-50.
5. Albihn PB, Savage GP. The bioavailability of oxalate from oca (*Oxalis tuberosa*). *J Urol*, 2001; 166: 420-422.
6. Albihn PB and GP Savage. The effect of cooking on the location and concentration of oxalate in three cultivars of New Zealand-grown oca (*Oxalis tuberosa* Mol). *Journal of the Science of Food and Agriculture*, 2001; 81: 1027-1033.
7. Andri Cahyo Kumoro et al. / *Procedia Chemistry*, Kinetics of Calcium Oxalate Reduction in Taro (*Colocasia esculenta*) Corm Chips during Treatments Using Baking Soda Solution, 2014; 9:102-112.
8. Anon. Dry Kiln Operator's Manual Handbook. Agriculture Handbook No-188. United State Department of Agriculture (USDA) for Service Forest Production Laboratory, Madison, And Wood Industry, 2001.
9. Anonymous, Proceedings of the Taro Collecting Strategy for the Pacific Islands Workshop; Aus AID/SPC Taro Genetic Resources: Conservation and Utilization. Secretariat of the Pacific Community, New Caledonia, 21p, 1999.
10. Arnavid-Vinas, M.D.R. and Lorenz, K. Pasta products containing Taro (*Colocasia esculenta*, L Schott) and chaya (*Cnidoscuculus chavamansa* L. Mcvaugh. *Journal of Food Processing and Preservation*, 1999; 23: 1-20.
11. Babar VD Preparation of tutti-fruity from bottle gourd. Mahatma Phule Agricultural University, Rahuri, India, 1996.
12. Babayemi, O. J.; Bamikole, M. A. Nutrient value and in vitro gas production of African wild cocoyam (*Colocasia esculentum*). *Afr. J. Food Agric. Nutr. Dev.*, 2009; 9(1): 593-607.
13. Baker and G.J Christopher. *Industrial Drying of Foods*. Blackie Academic and Professional, London, 1997.
14. Barot Amit M, Pinto S, Modha H Development of Technology for Manufacture of Bottle Gourd Ice Cream. *J Nutr Food Sci* 4: 316. doi: 10.4172/2155-9600.1000316, 2014.

15. Bhandari MR, Kawabata J Cooking effects on oxalate, phytate, trypsin and a-amylase inhibitors of wild yam tubers of Nepal, *J Food Compos Anal*, 2006; 19: 524-530.
16. Bradbury, JH, and Nixon, RW, The Acridity of Raphides from the Edible Aroids, *J Sci Food Agric.*, 1998; 76: 608-616.
17. Bradbury, J.H. and W.D. Holloway, *Chemistry of Tropical Root Crops: Significance for Nutrition and Agriculture in the Pacific*. Australian Centre for International Agricultural Research, Canberra, 1988.
18. Brune M., Rossander L. and Hallberg L. Iron absorption and phenolic compounds: importance of different phenolic structures. *European Journal of Clinical Nutrition*, 1989; 43: 547-558.
19. Buntha P, Borin K, Preston T, Ogle B Survey of taro varieties and their use in selected areas of Cambodia. *Livestock Research for Rural Development*, 2008; 20.
20. Chinnajarn, S., K. Lirnroong Reungrat, A. Sangnar and W.Y. Puttakal, Development of Health Chip from Jackfruit Seed Flour. Research Report, Faculty of Science, Burapha University of Chonbir, 2006.
21. Crabtree J. and Baldry J. Technical note: the use of Taro products in bread making. *Journal of Food Technology*, 1982; 17: 771-777.
22. CSA (Central Statistical Authority) of Ethiopia, Statistical Report on Area and Production of Crops, Farm Management Practices, Farm Implements, Machineries and Storage Mechanisms. Addis Ababa Ethiopia, 2004.
23. CSA, Crop Production Forecast Sample Survey. Ethiopia, Addis Ababa. Statistical Bulletin Number, 2010/11; 505.
24. Doubliel, J.L., P. Colona and C. Mercier, Extrusion of cooking and drum drying of wheat starch and rheological characteristic of starch pastes. *Cereal Chemistry*, 1986; 65: 240-246.
25. E. A. Baidoo et al Effect of Pre-treatment and Storage Condition on the Physicochemical Properties of Taro (*Colocasia esculenta* [L.] Schott) Flour, 2014.
26. Emmans G C Free choice feeding of laying poultry. in *Recent Advances in Animal Nutrition*, Haresign and D.Lewis, ed. Butterworths, London, UK, 2008; 31-39.
27. Emmanuel-Ikpeme, C.A., C.A. Eneji and U. Essiet, Storage stability and sensory evaluation of taro chips fried in palm oil, palmolein oil, groundnut oil, soybean oil and their blends. *Pakistan Journal of Nutrition*, 2007; 6(6): 570-575.

28. Esayas Ayele, A thesis submitted to the school of graduate studies of Addis Ababa University in partial fulfilment of the requirement for the degree of Master of Science in food science and nutrition, 2009.
29. FAO Roots, Tubers, Plantain and Bananas in Human Nutrition. Rome: Food and Agriculture Organization of the United Nations, 1990.
30. FAO (1992) Taro: A South Pacific specialty Leaflet - revised. Community Health Services, South Pacific Commission, B.P. D5 Noumea, Cedex, New Caledonia, 1992.
31. FAO, Taro Cultivation in Asia and the Pacific, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 1999.
32. FAO, Importance of Taro. Retrieved from; [http://www.fao.org/docrep/005/AC450e.Htm#](http://www.fao.org/docrep/005/AC450e.Htm#Top) Top of page, (access on: January 20, 2010), 2008.
33. Ghosho, S.K. and M.A. Hasan, Variation in sugar content of different taro (*Colocasia esculenta* (L.) Schott) cultivars. *Indian Agriculturalist*, 1992; 36: 57-59.
34. Goodenough RD, Stenger VA Magnesium, calcium, strontium, barium and radium. In: Bailar JL, Emeleus HJ, Nyholm R, Trotman AFD, editors. *Comprehensive Inorganic Chemistry*. Oxford: Pergamon Press, 1973; 591-664.
35. Greenwell, A. B. H. "Taro-with special reference to its culture and uses in Hawaii." *Economic Botany*, 1947; 1(3): 276-289.
36. Gubag, R., Omoloso, D.A. and Owens, J.D. Sapal: A traditional fermented Taro (*Colocasia esculenta* (L.) Schott) corm and coconut cream mixture from Papua New Guinea. *International Journal of Food Microbiology*, 1996; 28: 361-367.
37. Heredia, Z.N.A., Yield of five taro clones grown in the Pantanal region of Mato Grosso do sul. *Horticultura Brasileira*, 1995; 13: 38-40.
38. Hollyer, J.R., R.S. de la Pena; K.G. Rohrbach; L.M. LeBeck, Taro, mauka to makai: A Taro Production and Business Guide for Hawaii growers. 108pp., 1997.
39. Hong, G.P. and Nip, W.K. Functional properties of precooked Taro flour in sorbets. *Food Chemistry*, 1990; 36: 261- 270.
40. Huang, A.S. and L.S. Tanudjaja, Application of anion exchange high-performance liquid chromatography in determining oxalates in taro (*Colocasia esculenta* (L.) Schott) corms. *Journal of Agriculture and Food Chemistry*, 1992; 40: 2123-2126.
41. Huang CC, Chen WC, Wang CCR Comparison of Taiwan paddy- and upland-cultivated taro (*Colocasia esculenta* [L.] Schott) cultivars for nutritive values. *Food Chem*, 2007; 102: 250-256.

42. Hussain, M., Norton, G. and Neale, R.J. Composition and nutritive value of cormels of *Colocasia esculenta* (L) schott. *Journal of the Science of Food and Agriculture*, 1984; 35: 1112-1119.
43. Ihekoronye, A.I. and Ngoddy, P.O. Cocoyams. In: *Integrated Food Science and Technology for the Tropics*, Macmillan, London, 1985; 280-281.
44. Iwuoha CI, Kalu FA Calcium oxalate and physicochemical properties of cocoyam: *Colocasia esculenta* and *Xanthosoma sagittifolium* tuber flours as affected by processing, *Food Chem*, 1995; 54: 61-66.
45. James Hollyer¹, Robert Paull², and Alvin Huang³ *Food Manufacturing and Technology* Feb, 2000.
46. Jane, J., L. Shen, S. Lim, T. Kasemsuwantt and K. Nip, Physical and chemical studies of taro starches and flours. *Cereal Chemistry*, 1992; 69: 528–535.
47. Kelsav JL Effect of oxalic acid on calcium bioavailability. In Kies C, editor. *Nutritional Bioavailability of Calcium*. Washington DC: American Chemical Society, 1985; 105-116.
48. Kochhar, S.I., *Economic Botany in the Tropics*. MacMillan Indian Limited. Delhi, 1998.
49. Kwarteng, J.A. and M.J. Towler, *West African Agriculture. A Textbook for Schools and Colleges*. Macmillan Pub. London, 1994; 128-129.
50. Lebot, V., Biomolecular evidence for plant domestication in Sahul. *Genetic Resources and Crop Evolution*, 1999; 46: 619-628.
51. Liu, Q., E. Donner, Y. Yin, R.L. Huang and M.Z. Fan, The physicochemical properties and in vitro digestibility of selected cereals, tubers, and legumes grown in China. *Food Chemistry*, 2006; 99: 470-477.
52. Lucy, M, E. Reed and B.R.Glick, Application of free living plant growth-promoting Rhizobacteria. *Antonie van Leeuwenhoek*, 2004; 86: 1025.
53. Malavanh Chittavong, T R Preston and B Ogle b: Ensiling leaf of Taro (*Colocasia esculenta* (L.) Schott) with sugar cane molasses. *Livestock Research for Rural Development*, supplement, 2008; 20. from <http://www.lrrd.org/lrrd20/supplement/mala1.htm>
54. Mandhyan, B.L., C.M. Abroal and A.R. Tyagi, Dehydration characteristics of winter vegetables. *Journal of Food Science and Technology*, 1988; 25(1): 20-22.
55. Mevl t TEN, Atilla AKG L, Musa ZCAN, Physical and Chemical characteristics of Taro (*Colocasia esculenta* (L.) Schott) Corms and Processing to Chips and Puree, 2000.

56. Mosha TC, Gaga HE, Pace RD, Laswani HS and Mtebe K Effect of blanching on the content of antinutritional factors in selected vegetables. *Plant Foods for Human Nutrition*, 1995; 17: 361-367.
57. Nip, W.K., Taro root. In: D.S. Smith, J.N. Cash, W.K. Nip, Y.H. Hui, (Eds.). *Taro: Processing Vegetable and Technology*. Technomic Publishing, Pennsylvania, USA, 1997; 355–387.
58. Nip, W.K., J. Muchille, T. CAI and J.H. Moy, Nutritive and non-nutritive constituents in taro (*Colocasia esculenta* (L.) Schott) from American Samoa. *Journal of Hawaii Pacific Agriculture*, 1989; 2: 1-5.
59. Njintang N.Y., C.M.F Mbofung., A. Abdou bouba, Aboubakar, M. Parker, C. Faulk, A. Smith, M. Graham, R. Bennett and W.K. Waldron 2003 Major Constraints Associated with the use of Taro (*Colocasia esculenta*) Flour as Raw Material for the Preparation of Achu. A proceeding paper presented during the Agro-Food Enterprise of Food-Africa in May 2003. http://foodafrica.nri.org/enterprises/enterprises_proceedings/42-njintang.doc Retrieved: August 17, 2011.
60. Njintang, N.Y., M.F. Mbofung and R. Kesteloot, Multivariate analysis of the effect of drying method and particle size of flour on the instrumental texture characteristics of paste made from two varieties of taro flour. *Journal of Food Engineering*, 2007; 81: 250-256.
61. Njintang, Y.N. and Mbofung, C.M.F. Development of Taro (*Colocasia esculenta* L. Schott) as an ingredient for food processing: Effect of gelatinisation and drying temperature on the dehydration kinetics and colour of flour. *Journal of Food Engineering*, 2003; 58, 259-265.
62. Njintang, Y., F. Mbofung, F. Balaam, P. Kitissou and J. Scher, Effect of taro (*Colocasia esculenta* (L.) Schott) flour addition on the functional and alveographic properties of wheat flour and dough. *Journal of Agriculture and Food Science*, 2008; 88: 273-279.
63. Noonan S.C. and Savage G.P. Oxalic acid and its effects on humans. *Asia Pacific Journal of Clinical Nutrition*, 1999; 8: 64-74.
64. Obiechina, O.C. and Ajala, A.A. Socioeconomic and cultural importance of cocoyam as staple food. *Proceedings of First National Workshop on Cocoyam*, NRCRI, Umudike, 1987; 180-184.
65. Onayemi O. and Nwigwe C. Effect of processing on the oxalate content of cocoyam. *Food Technology*, 1987; 20: 293-295.

66. Onwueme, I.C. Colocasia and xanthosoma. In Tropical Tuber Crops, John Wiley and Sons, New York, 1978; 199-227.
67. Onwueme, I.C. Tropical root and tuber crops - Production, perspectives and future prospects. FAO Plant Production & Protection Paper 126, FAO, Rome, 1994; 228.
68. Onwueme, I.C. and T.D. Simha, Field Crop Production in Tropical Africa. CTA Ed, Netherlands, 1991; 276-288.
69. Onwueme, Inno Taro cultivation in Asia and the Pacific. Published in RAP Publication 1999/16. Published by Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, 1999,
<http://www.fao.org/DOCREP/005/AC450E/ac450e03.htm#TopOfPage>
70. Onyeike, E.N., T. Olungwe and A.A. Uwakwe, Effects of heat treatment and defatting on the proximate composition of some Nigerian local soup thickeners. Journal of Food Chemistry, 1995; 53: 173-175.
71. Opara, L.U. Edible aroids-Post operation. FAO, Rome, 2000.
72. Oscarsson K.V. and Savage G.P. Composition and availability of soluble and insoluble oxalates in raw and cooked Taro (*Colocasia esculenta* var. Schott) leaves. Food Chemistry, 2007, 101: 559-562.
73. Osisiogu, I.U., J.O. Uzo and E.N. Ugochukwu, The irritant effects of Cocoyams. *Planta Medica*, 1974; 26: 166–169.
74. Paul R.E., Tang C.S., Gross K. and Umu G. The nature of the tannin acidity factor, *Postharvest Biology Technology*, 1999; 16: 71-78.
75. Perez E, Schultzb FS, de Delahaye PE Characterization of some properties of starches isolated from *Xanthosoma Sagittifolium* (tannia) and *Colocasia esculenta* (taro). *Carbohydrate Polym*, 2005; 60: 139-145.
76. Pheng Buntha; Khieu Borin; Preston, T.R.; Ogle, B. Digestibility and nitrogen balance studies in pigs fed diets with ensiled Taro (*Colocasia esculenta*) leaves as replacement for fish meal. *Livest. Res. Rural Dev.*, 20 (suppl), 2008.
77. Polomy, J. Natural toxic substances in food [online]. Translated from Czech.
78. <http://www.ncbi.nlm.nih.gov/pubmed/9264873>[Accessed 21 June 2007], 1997.
79. Ramanatha, R.V., J. Matthews Peter, B. P. Eyzaguirre, D. Hunter, The Global Diversity of Taro: Ethnobotany and Conservation. Biodiversity International, Rome, Italy, 2010.
80. Ranganna (Second Edition). Handbook of Analysis and Quality Control for Fruits and Vegetable products, 2001.

81. Safo Kantaka, O. *Colocasia esculenta* (L.) Schott. Record from Protabase. Grubben, G.J.H. & Denton, O.A. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands, 2004.
82. Sakai WS Aroid root crops. In Chan HT, editor. Handbook of Tropical Foods. New York: Marcel Dekker, 1983; 29-83.
83. Sasanka Sekhar Dash, P. Gurumoorthi. Studies on Effects of Processing on Oxalate Content in Agricultural Produce (*Colocasia esculenta*, *Prunus dulcis*, *Glycine max*) .Internet Journal of Food Safety, 2011; 13: 270-274,
84. Savage, G.P. and D.J. Catherwood, Determination of oxalates in Japanese taro corms using an in vitro digestion assay. Food Chemistry, 2007; 105: 383-388.
85. Schempf JM, Freeberg FE, Angelon FM. Effect of sodium ion impurity on thermal decomposition reaction of calcium oxalate as studied by absorption infrared spectrometric and thermo analysis techniques. Anal Chem, 1965: 37(13): 1704-1706.
86. Shanthakumari S, Mohan V, De Britto J Nutritional and antinutritional evaluation of wild yam (*Dioscorea* spp.). Trop Subtrop Agroecosyst, 2008; 8: 313-319.
87. Smith DL Calcium oxalate and carbonate deposit in plant cells. In Anghileri, LJ, and Tuffet-Anghileri IS, editors. The Role of Calcium in Biological Systems. Boca Raton: CRC Press, 1982; 253-261.
88. Souady ID, Delatour P, Grancher D Effects of traditional soaking on the nutritional profile of taro flour (*Colocasia esculenta* L. Schott) produced in Chad. Revue Méd Vét, 2010; 1: 37-42.
89. Standal, B.R., Nutritive value. In: J.K. Wan (Eds.). Taro: a review of *Colocasia esculenta* (L.) Schott and its potentials. University of Hawaii Press, Honolulu, 1983; 141-147.
90. Tsami, E., M.K. Krokida and A.E. Drouzas, Effect of method drying on sorption characteristics of model fruit powders. Journal of Food Engineering, 1999; 38: 381-392.
91. Use of Food Additives in Food Products (FSSA Corrigendum Tables)
92. Vega-Mercado, H., M.M. Gongora-Nieto and G.V. Barbosa-Canovas, Advances in dehydration of foods. Journal of Food Engineering, 2001; 49: 271-289.
93. West B. J., Tani H., Palu AK, Tolson C.B. and Jensen C.J. Safety tests and antinutrients analyses of noni (*Morinda citrifolia* L.) leaf. Journal of the Science of Food and Agriculture, 2007; 87: 2583 - 2588.
94. Wilson, J. E.; Siemonsma, J. S. *Colocasia esculenta* (L.) Schott. Record from Proseabase. Flach, M. & Rumawas, F. (Editors). PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, 1996.

APPENDICES**Appendix-I****Score Card-1 for Sensory Evaluation of Tutti Fruity**

Directions: Please taste the samples one by one and evaluate them for the following parameters on hedonic scale as given at the end of form. It is very important to rinse mouth thoroughly with clean water after evaluation of each sample.

Panellist Name: _____

Age: _____

Sex: Male /Female

Date: _____

Signature: _____

Sample I	Flavour	Texture	Taste	Appearance	Presence of Itching Yes/No	Overall Acceptability
a						
b						
c						
d						
e						
f						
g						
h						
i						
j						

Hedonic scale

1. Dislike Extremely
2. Dislike Very Much
3. Dislike Moderately
4. Dislike Slightly
5. Neither Like or Dislike
6. Like Slightly
7. Like Moderately
8. Like Very Much
9. Like Extremely

Score card-2 for sensory evaluation of tutti fruity

Directions: Please taste the samples one by one and evaluate them for the following parameters on hedonic scale as given at the end of form. It is very important to rinse mouth thoroughly with clean water after evaluation of each sample.

Panellist Name: _____

Age: _____

Sex: Male /Female

Date: _____

Signature: _____

Sample II	Flavour	Texture	Taste	Appearance	Presence of Itching Yes/No	Overall Acceptability
a						
b						
c						
d						

Hedonic scale

1. Dislike Extremely
2. Dislike Very Much
3. Dislike Moderately
4. Dislike Slightly
5. Neither Like or Dislike
6. Like Slightly
7. Like Moderately
8. Like Very Much
9. Like Extremely

Sample III	Flavour	Texture	Taste	Appearance	Presence of Itching Yes/No	Overall Acceptability
a						
b						
c						
d						
e						
f						

Score card-3 for sensory evaluation of tutti fruity

Directions: Please taste the samples one by one and evaluate them for the following parameters on hedonic scale as given at the end of form. It is very important to rinse mouth thoroughly with clean water after evaluation of each sample.

Panellist Name: _____

Age: _____

Sex: Male/Female

Date: _____

Signature: _____

Hedonic scale

1. Dislike Extremely
2. Dislike Very Much
3. Dislike Moderately
4. Dislike Slightly
5. Neither Like or Dislike
6. Like Slightly
7. Like Moderately
8. Like Very Much
9. Like Extremely

APPENDIX-II

Table 12: Calculation of fiducial limits of Control sample in terms of Overall acceptability

S. No	Scores of Control sample, X	Squares of scores, X ²
1	1	1
2	1	1
3	2	4
4	1	1
5	2	4
6	1	1
7	1	1
8	1	1
9	2	4
10	1	1
11	2	4
12	1	1
13	2	4
14	1	1
15	2	4
16	1	1
17	1	1
18	1	1
19	2	4

20	2	4
21	1	1
22	1	1
23	1	1
24	2	4
25	2	4
26	1	1
27	2	4
28	1	1
29	1	1
30	1	1
Sum	X=41	X²=63

CALCULATION

$$\text{Mean Score } \bar{X} = 41 \div 30 = 1.366$$

$$\begin{aligned} \text{Sum of squares of deviations from the mean (i.e., variance, } s^2) &= \{\sum X^2 - (\sum X)^2 \div N\} \div N \\ &= \{63 - (41)^2 \div 30\} \div 30 \\ &= \{6.967\} \div 30 = 0.2322 \end{aligned}$$

$$\text{Standard deviation (s)} = \sqrt{0.2322} = 0.4818$$

$$\text{Standard error of the mean (SE)} = 0.4818 \div \sqrt{(30-1)} = 0.0894$$

Calculation of limits

$$t \text{ value from Table 19-11(S. RANGANNA) for } n-1 = 29 \text{ degrees of freedom}$$

$$t \text{ at 5\% level} = 2.04$$

$$t \text{ at 1\% level} = 2.76$$

$$\text{Limits (L)} = SE \times t$$

$$\begin{aligned} \text{Fiducial limits (FL) at 5\%} &= \text{Mean score (X)} \pm \text{Limits (L)} \\ &= 1.366 \pm 2.04 \\ &= 1.1837 \text{ to } 1.5483 \end{aligned}$$

$$\begin{aligned} \text{Fiducial limits (FL) at 1\%} &= 1.366 \pm 0.2467 \\ &= 1.366 \pm 0.2467 \\ &= 1.1193 \text{ to } 1.6127 \end{aligned}$$

RESULT

After determining the fiducial limits of Control sample at 1% ($p < 0.01$) and 5% ($p < 0.05$) levels. From table 10, Sample 2d mean value falls in the fiducial limits of Control sample at 1% ($p < 0.01$) level, so Sample2d (Boiling at 100°C for 60mins in 60% Tamarind pulp) is significantly superior to all samples and sample1i (Blanched at 90°C for 3mins in 60% Tamarind pulp) and sample2e (Boiling in Water at 100°C for 60mins) are significantly inferior to the sample2d at 1% level ($p < 0.01$).