BREAD MAKING POTENTIALS OF FLOUR FROM TARO (*Colocasia esculenta* L.) AS A PARTIAL SUBSTITUTE OF WHEAT FLOUR

MSc. THESIS

BY

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JIMMA UNIVERSITY

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We, the undersigned, member of the Board of Examiners of the final open defense by **Misgana Benti** have read and evaluated his/her thesis entitled "**Bread Making Potential of Flour from Taro(Colocasia Esculenta) Varieties as a Partial Substitute of Wheat Flour**" and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Food Science and Technology**

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DEDICATION

This thesis work is dedicated to My Lovely Father Banti Naguma whom I missed long ago!

STATEMENT OF THE AUTHOR

I declare that this thesis is my own work and that all sources of material used in writing up of this thesis have been recognized and acknowledged accordingly.

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BIOGRAPHICAL SKETCH

Misgana Banti was born on October 18, 1991 in Mene Sibu woreda of West Wollegga zone, Oromiya Regional State, Ethiopia. He attended his primary education at Tenki primary school found nearby his home village. He continued his junior secondary school at Mendi elementary school in Mendi town. Then, he attended his high school and preparatory from 2007 to 2010 at Mene Sibu High School in Mendi town. The author joined Jimma University College of Agriculture and Veterinary Medicine in September 11, 2010 G.C and graduated with Bachelor of Science Degree (B.Sc.) in Post-harvest Management on July 7, 2013 G.C.

After his graduation, he was employed by Ethiopian Institute of Agricultural Research as junior researcher in Food Science and Nutrition research division of the Institute, and has been assigned to Jimma Agricultural Research Center (JARC). He served JARC for three years; two years as junior researcher and one year as an Assistant researcher I. In 2017, he has joined Jimma University College of Agriculture and Veterinary Medicine to pursue his post graduate study (MSc.) in Food Science and Technology.

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LIST OF ABBREVIATIONS AND ACRONYMS

A4NH	Agriculture for nutrition and health
AAS	Atomic Absorption Spectrophotometer
AOAC	Association of Official Analytical Chemists
BD	Bulk Density
CEA	Central Statistics Authority
CME	Colocassia Methanol Extracts
DPPH	2, 2-Diphenyl-1- Picrylhydrazyl
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization
FRAP	Ferric Reducing Antioxidant Power
JARC	Jimma Agricultural Research Center
MPA	Meta- Phosphoric Acid
OAC	Oil Absorption Capacity
RDA	Recommended Daily Allowance
SP	Swelling Power
WAC	Water Absorption Capacity
WSI	Water Solubility Index

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ABSTRACT

Bread is the main food product of wheat which is widely consumed throughout the world. Nonetheless, a continuous increase in the price of wheat is raising serious concern on the economic feasibility of wheat importation by developing countries including Ethiopia. Thus, this study investigates the nutritional, anti-nutritional and phytochemical composition, functional and antioxidant properties of flours from different taro varieties to select the most suitable variety for bread making as a partial substitute of wheat flour. Wheat flour was replaced with 7.5- 30% taro (Kihaque variety) flour using mixture design and various quality attributes of composite breads were studied. Chemical composition and bread baking were determined using the AOAC and the straight-dough standard methods, respectively. Results showed that the moisture, crude- proteins, fat, fiber, and total ash, carbohydrate and gross energy contents for taro flours ranged from 5.25 to 7.84, 4.03 to 9.28, 0.160 to 1.23, 2.96 to 5.06, 5.30 to 7.14, 81.1 to 85.4 (in g/100 g) and 354 to 372 in Kcal/100 g on dry weight basis (dwb), respectively. The mineral composition of flour from taro varieties/accessions were K (1375 to 2525), P (111 to 397), Mg (269 to 209), Ca (31.7 to 120), Zn (17.0 to 62.0), Na (20.0 to 30.0), Fe (7.31 to 20.7) and Mn (0.650 to 13.2) mg/ 100 g dwb. Oxalate, phytate, and condensed tannin contents of taro varieties/accessions ranged from 24.3 to 56.7, 6.28 to 28.9 and 57.4 to 134in mg/100 g, respectively. The total phenolic, flavonoids, β-carotene and ascorbic acid contents of the varieties ranged from 39.5 to 57.8 mg gallic acid equivalents GAE / g dwb, 4.67 to 6.27 mg catechin equivalents CE/ g dwb, 10.4 to 18.5 and 11.0 to 13.0 mg/ 100 g dwb, respectively. DPPH inhibition percentages of 25.5 to 34.7% *and* 62.0 to 83.7% *at lowest and highest concentrations, respectively and FRAP values between 122% and 188% were obtained for different taro varieties. Water absorption capacity, oil absorption capacity, water solubility index and dispersibility of the flours ranged from, 228 to 331 %, 176 to 216 g/100 g 19.2 to 24.4 g/100 g, 18.7 to 26.7 respectively. Loaf weight of breads tends to increase with increasing proportion of taro flour, while loaf volume was the highest at 15% level of substitution and the specific volume was found to be maximum for control bread. Except for moisture and protein contents, other proximate compositions and energy values of composite breads were affected by taro flour blending ratios. An increase in the proportion of taro flour in the composite has resulted in less degree of liking by the consumer panels. In general, it appears that taro flour inclusion led to slightly reduced bread sensory quality when substituted greater than 15%. Further work, however, needs to be done to explore more in-depth quality attributes of bread such as rheological and health promoting properties of bread to have a complete picture on the quality of wheat-taro composite flour bread.*

Keywords: blending ratio, bread quality, composite flours, root crops, taro, wheat substitutes

1. INTRODUCTION

Bread is one of the most popular foods widely consumed in Ethiopia and worldwide (Abera *et al*., 2017). It is a calorie-rich food that represents a major source of energy in human nutrition. Commonly, it is made with cereals. Wheat is the most important cereal grain used for bread making due to its gluten proteins (glutenins and gliadins) which are responsible for the unique viscoelastic dough that is suitable for leavened baked products (Ribeiro *et al*., 2018). Wheat is widely consumed in many African countries and ranks third after maize and cassava for daily caloric supply (Chapoto, 2010).

Ethiopia is the second largest wheat producer in sub-Saharan Africa, following South Africa (Bereket *et al*., 2014). However, in Ethiopia and many African countries, governments import wheat as a result of increasing demand for baked products following urbanization and a steadily growing population. This has resulted in continuous increases in the price of wheat making it more expensive in international markets. This represents a major burden on the economy of importing countries and raising a concern on feasibility of wheat importation by some African countries including Ethiopia. Therefore, there is a growing demand to promote the use locally produced and underutilized foods such as root crops for partial substitution of wheat flour in baking (Abass *et al*., 2016). Taro flour has been identified for partials substitution of wheat flour in bread making in other developing countries (Alflen *et al*., 2016; Ammar *et al*., 2009; Njintang *et al*., 2008).

Taro (*Colocasia esculenta*) called as 'Godare' in Ethiopia is tuberous tropical food crop belonging *to Araceae* family (Simon 1992). As farther stated by this author, it is staple food crops throughout the hot and humid areas of southwestern Ethiopia. The protein and fat content of taro are low but it is high carbohydrate (CHO) content and is a source of high caloric food, fiber, minerals, vitamin C and vitamin B-complex (Amon *et al*., 2014; Adane *et al*., 2013; Lim 2016). Taro has been reported to have 70% to 80% starch of which the granule size of corm's starch is small and easily digestible (98.8%) (Ubalua, 2016). Taro corm is also considerable source for different bioactive compound such as phenolics and flavonoids possessing antioxidant activities (Kumar *et al*., 2017).

Taro is usually consumed either as staple or mixed with other vegetables after cooking (Amon *et al*., 2014). Traditionally, taro can be eaten boiled or fried as a substitute for potatoes in tropical and subtropical areas of the world (Apata *et al*., 2012). Taro is also used in preparation of different traditional meals in many African countries (Akwee *et al*., 2015). Another very common use of taro is to process it as flour, which is the base for preparing the different types of food such as cookies and bread (Trinidad *et al*., 2010). The successful performance of taro flours as food ingredients has been reported to be attributed to the functional characteristics, which in turn are attributed to proteins and the complex carbohydrates such as pectins and mucilages (Kaur *et al*., 2013). It has been suggested that the small particle size of flour starch makes it useful for bread or noodle production (Aprianita *et al*. 2009).

1.1. Statement of the problem

Taro has a tremendous potential to store food reserves, as a major starchy food source in a number of regions across the humid and sub-humid tropics. In Ethiopia, taro is widely grown and popularly consumed mostly in south western Ethiopia (Cochrane *et al*., 2018). In this region and other parts of Ethiopia where it is cultivated, the crop has both cultural and social significance (Degefa *et al*., 2017). However, taro remains one of the most neglected crops and underutilized for human diet among other communities in different regions of the country largely due to poor awareness of taro as food sources. Thus, the image of taro as food lags behind other crops and it is most commonly considered as "poor people's food" (Akwee *et al*., 2015).

Despite the versatility of taro for different food applications in many African countries, there is limited interest to process taro into flour for various food product development including in areas where it is considered staple food sources, Southern Ethiopia (Banjaw *et al*., 2017). It is hypothesized that this may be due to lack of proper knowledge of nutritional potentials of the crop. This could be due to the lack of sufficient research to unlock their potential use in food formulations. Tubers of taro have a short-shelf life because of their high moisture content. Processing tubers of taro into flour has been proposed as one of the best ways to preserve taro tubers (Perez *et al*., 2005). Year round availability of taro flour may help to reduce

dependency on wheat flour in developing countries like Ethiopia which has significant economic implication. This could be a strategy to use local resources for producing low cost foods, such as bread and baked foods and also enhance the economic value of taro as being promoted by many development partners. Information on the food value of taro varieties will encourage local dweller to use of taro flour for food preparation, which will in turn encourages improved cultivation of this crop. Therefore, this study was commenced with the following general objective and specific objectives which was intended to help in selection of better variety for possible use of its flour in bread making.

1.2.Objectives of the study

1.2.1. General objective

- To evaluate the bread making potentials of taro flours for identification of the best variety for partial substitution of wheat flour toward its popularization.

1.2.2. Specific objectives

The specific objectives of the study were to:

- identify the variety with fairly good nutritional composition
- investigate the variety with lower contents of anti-nutritional factors
- study functional properties of taro flour for their suitability in food system
- identify the variety with high potential for its phytochemical composition and antioxidant property
- evaluate the bread making quality of taro flour through partial substitution of wheat flour

1.3. Significance of the study

The results revealed in this study would help different stake holders who have been and will be dealing with taro in one or the other ways. The results are helpful for researchers working with the crop under different discipline varying from breeders, extensions, agricultural economists to food scientists. Farmers producing the crop could also benefit from the crops

through training and extension process. Moreover, government could also gain its own share provided that recommended results will be implemented with farther proposed verifications.

1.4. Limitation of the study

One research project can hardly implement without limitations. Some of the limitations we come across while doing this research were the budgetary problems both in terms of amount and timely release issue. Problem related to laboratory facilities including chemicals and reagents were also there though we have tried to the maximum of our capacity to tackle or else minimize these problems through discussion with the department and other responsible bodies.

1.5. Experimental plan

The experiment was plan as per indicated in the following flow diagram.

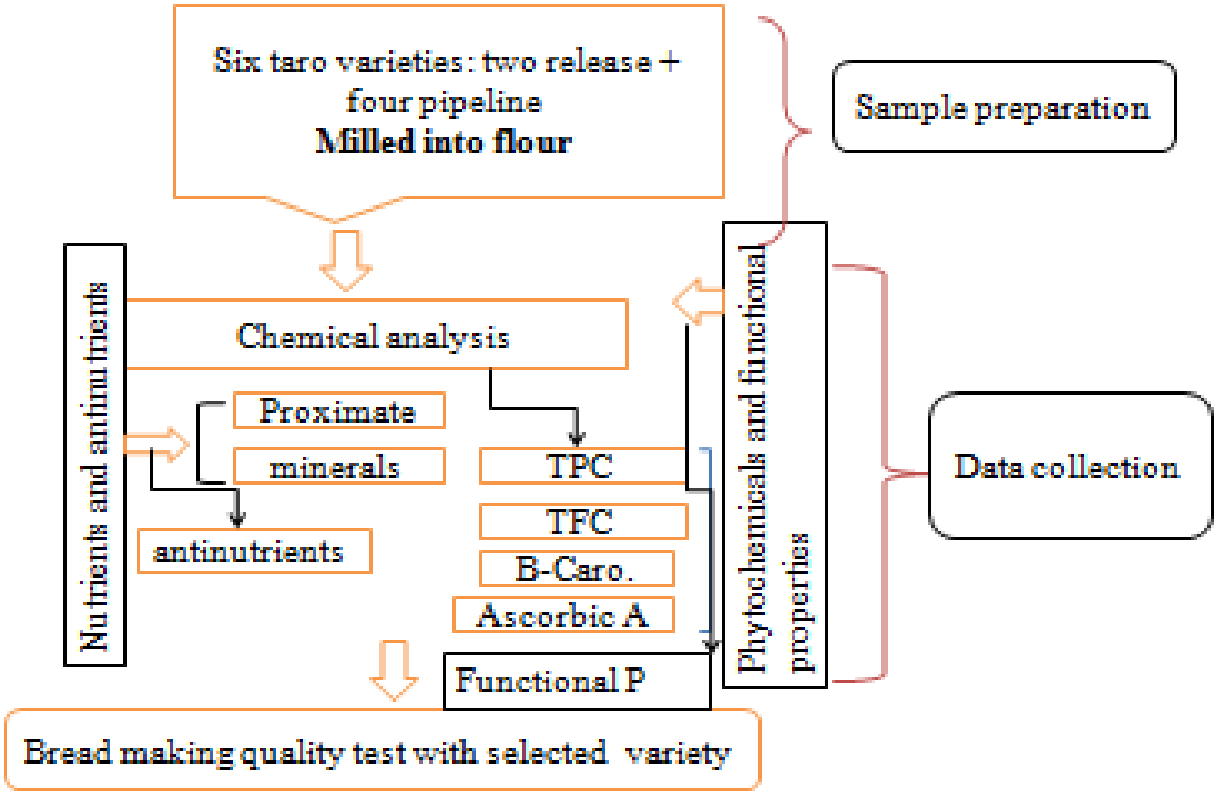


Figure 1.1: Experimental plan

2. LITERATURE REVIEW

2.1. Taxonomy and botanical specifications of taro

Taro (*Colocasia esculenta* (L.) Schott) is an herbaceous, perennial stem root crop widely cultivated in tropical and subtropical regions of the world. The name taro is generally used to refer to *Colocasia esculenta*, one of several major root crops in the Araceae family and is belongs to the genus *Colocasia*, sub-family Colocasioideae (Winter 2012).

2.2. Global overview of current taro production statistics

Roots and tuber crops are the second-most produced group of crop species after cereals and are produced relatively with low agricultural inputs (Chandrasekara *et al*., 2016). According to Onyeka (2014), West Africa is by far the principal taro producing region in the world. As it is farther stated in the above journal, Africa accounted for 86% of global area harvested and 74% of total taro production within the last five year (from 2008-2012). Taro is of particular significance in many Pacific Island countries where it forms fraction of the staple diet and serves as an export commodity (Bammite *et al*., 2018). In general, tropical and subtropical regions of Asia, Africa and Latin America are known region across the globe to cultivate and consume taro.

Taro can be considered food security crop as it has advantages of high yielding in terms of energy per hectare, not seriously attacked by pests or diseases, and drought tolerance (Akwee *et al*., 2015). Taro can also store for annually persistent food shortage from February to June (peaking in March to May) without much problems (Simon 1992). According to the author above, taro is grown for consumption, for sale and gifts as well in different parts of the world.

2.3. Production and utilization of taro in Ethiopia

In Ethiopia, roots and tubers including taros are grown widely in the Southern, Southwestern and Western region of the country and are important food items as well as an income source to the farmer (CSA 2013). As indicated in this report, SNNP is the major taro producing region (produces 74%) followed by Oromiya (23%).The remaining three percent is shared by

Gambela and Benishangul regions. In 2015/16 cropping season, the total taro production area was about 48,523.71 hectares and the production at the time was estimated to be over 12,112,217.6 quintals in Ethiopia (Getachew *et al*., 2016). Cochrane *et al*. (2018) reviewed CSA and reported that, taro corm crops production in Ethiopia by 2014, 2015 and 2016 were 270.4, 279.8, 297.81Q/ha respectively out of which 283.72, 302.61 and 259.87 Q/ha belongs to SNNP.

Cultivation and consumption of taro and other roots and tuber is very indigenous in Ethiopia, especially Southern region. As it is reviewed by Tewodros *et al*., 2014, farmers in Ethiopia know different cultivars of taro and plant within their farmland for home consumption. The authors elaborated this by their review of the report by Simon, 1992 which states that farmers have identified about eight taro cultivars cultivated locally and named as Gerezua, Shishia, Yiteria, Molia, Tawayia, Gessa, Dolka and Yeda, on the bases of variations in morphological, phonologic, agronomic and quality traits, its fitness into cropping systems and medicinal values. Taro is mainly produced for food purpose in Ethiopia and there are different shares of utilization forms in regions of Omo in Ethiopia.

Table 2.1: Utilization forms of taro corms

Statistical measures	Percent share allocated to:			
	Sales	Domestic consumption	Planting material	Making gifts
Mean	40.7	37.4	15.5	6.4
Maximum value reported	63. 0	59.0	30.0	1 0. 0
Minimum value reported	11. 0	16. 0	11. 0	3. 0

Source: Simon 1992

2.4. Nutritional composition of taro

Roots and tubers are fair source of nutrients and hence contribute significantly to food and nutritional security (Sharma *et al*., 2016). According to these authors, tropical roots and tubers, including sweet potato, cassava, taro, and yam are rich in starch and serve as staple foods in many countries. However, tubers and roots in general including taro are not a

sufficient source of fat. With respect to vitamins and minerals, they can considerably contribute to meet the recommended dietary needs of certain minerals and vitamins. Taro is a fair source of dietary fibers and good levels of some of the valuable B-complex group of vitamins (Sharma *et al*., 2016).

Table 2.2: Comparative of proximate composition of taro with wheat flour

Parameters (%)	Taro flour		
	Sharma *et al*.,2016	Darkwa *et al*., 2013	Hossain 2016
Moisture	-	14.68	8.55
Protein	0.8	3.43	4.85
Fat	1.0	4.01	0.65
Fiber	0.4	0.18	1.87
Ash	2.2	3.43	4.38
Carbohydrate	-	74	79.70
Energy (Kcal)	93.93	-	187

Taro flour contains appreciable amounts of minerals as can be understood from their ash content shown in table above. The available carbohydrate composition of taro is comparable to that of wheat flour or even a little beat better than wheat (68.75) (Hossain 2016). As explained further by this author, crude fiber levels of wheat (1.7%) and taro (1.87%) flours are also comparable. With respect to fat content, both wheat and taro flours are generally low and this value is relatively comparable in literatures indicated in the table 2 above. Protein content in taro is relatively lower than that of wheat 12.5% as it is reported by the author. From this report, one can simply understand that taro is as good source of carbohydrate, minerals and fiber comparable to cereals and even in some cases better source than cereal counterparts.

2.4.1. Proximate composition

Taro corm contains high moisture content as high as 75% on its fresh weight basis (Hair *et al*., 2003, Sharma *et al*., 2016). However, taro corm could be dried and milled into flour for the purpose of extending shelf life and product development in which its moisture content may be

as low as 5.74-10.30% (Adane *et al*., 2009, Moon *et al*., 2010). Taro as it is reported in different literature are considerable source of dietary fiber ranging between 2.2-3.38% as indicated in Adane *et al*. (2009) and Soudy *et al*. (2010) and this fiber is known for its different health advantages. According to Adane *et al.* (2009), Alcantara *et al*. (2013) and Darkwa *et al*.(2013) the ash content of taro corm flour is also high and ranges between 2.78% and 4.92% on dry basis.

Carbohydrates composition of taro tuber is very high and can range between 73 to 80% in different literatures (Adane *et al*., 2009, Darkwa *et al*., 2013). The broad range of protein content of taro flour between 2.2% and 8.07% was also reported by different authors (Alcantara *et al*., 2013, Darkwa *et al*., 2013 Soudy *et al*., 2010). Similar to other roots and tuber crops, low fat content which may ranges between 0.4% to 3.68% are indicated for taro in literatures across the globe (Adane *et al*., 2009, Alcantara *et al*., 2013, Hair *et al*., 2003). The taro corm flour can be considered a significant source of dietary energy which could range between 135 Kcal/100g to 376.78Kcal/100g as reported in literature across the world (Adane *et al*., 2009 and Sharma *et al*., 2016).

2.4.2. Micronutrient composition of taro corm flour

Taro can also considered as fair source of micronutrients (minerals and vitamins). It is considerable source of different mineral micronutrients (Hair *et al*., 2003). These authors reported the mineral composition of taro to be 34 mg of calcium per 100 gram of raw taro, 62 mg of phosphorous per 100g of raw taro, 1.2 mg of iron per 100g of raw taro. Adane *et al*. (2009) studied mineral content of raw taro sample from variety Acc.236000 and reported the minerals contained in taro to be, Fe (6.08mg/100g), Zn(48.16mg), Ca (31.81mg/100g), Na (14.58mg/100g), Mg (7.32mg/100g), Cu (0.46mg/100g), Mn (1.27mg/100g) and P (13.50mg/100g). There is wide variability in specific mineral content reported in literatures across the world which probably attributed to wide variation between taro varieties, geographic conditions, methods of processing and analysis and other possible factors. The table indicated below is a good example to indicate the variability.

Table 2.3: Mineral composition of taro corms

Minerals	a	b	c
Sodium	11-25	82-113	13.81-14.58
Potassium	354-861	2251-4143	-
Phosphorus	87-124	158-340	7.77-13.50
Iron	1.71-1.44	8.1-10.8	5.86-6.08
Zinc	0.17-0.21	-	43.08-48.16
Manganese	-	-	1.27-3.61
Magnesium	41-69	118–219	7.24-7.32
Calcium	38-65	31-47	31.81-45.23

(a-Huang *et al*., 2000, b-Huang *et al*., 2007, c- Adane *et al*., 2009)

The level of some vitamins in taro corms are reported as thiamin 0.09 mg/100g, riboflavin 0.03 mg/100g and niacin 0.4 mg/100g (Roy *et al*., 2003).Taro corm is also reported in literatures as fair in ascorbic acid, a vitamin having considerable antioxidant capacity (Kumar *et al*., 2017). The ascorbic acid content of fresh raw corms and cormels were 31.54 and 29.16 mg/ 100 g (dry weight) (James *et al*., 2013, Nguimbou *et al*. (2013) respectively while for flour of taro corm, ascorbic acid content is about 8.95mg/100g. Taro corm is also reported to be fairly rich in beta-carotene, precursor of vitamin A as reported by Kumar *et al*. (2017). Beta-carotene content is about 5.9mg/100g and 19 in mg/100g in taro as reported by Nguimbou *et al*. (2013) and Isabelle *et al*. (2010) respectively. Huang *et al*. (2007) also reported beta-carotene contents of taro corms which range from 74.4 to 93.61 mg/100 g.

Table 2.4: Vitamin composition of taro corm flours

Vitamin	mg/100g					
	a	b		c	d	e
		Lehua Varity	Bun-Long Variety			
β-Carotene		74.40	93.61			<5
Ascorbic acid	4.5	15	12	14.3	7-9	<1
Thiamin	0.10	0.05	0.07	0.028	0.18	0.11
Riboflavin	0.03	0.06	0.05	0.029	0.04	0.02
Niacin	0.60	0.64	0.82	0.78	0.9	1.3

Source: a-Maga *et al*. (1992), b- Huang *et al*., 2000, c- Hedges and Lister (2006), d- Fungi 2012 and e- Kumar *et al*., 2006

2.4.3. Phytochemicals composition of taro corm

The corms and leaves of taro contain diversity of non nutritional compounds considered helpful to protect from chronic problems (Adegunwa *et al*., 2011, Olajide *et al*., 2011, Sharma *et al*., 2016). These compounds are reported of possessing antioxidants and anti-inflammatory properties (Duangmal *et al*., 1999, Cambie *et al*., 2003) and significant role in the proper control and management of chronic diseases (Kim *et al*., 2002, Trinidad *et al*., 2010). Phenolic acids are considered important group of these antioxidant compounds (Padda *et al*., 2007). Total phenolic compound of about 0.12 mg of GAE/g by Amon *et al*. (2014), 0.75 mg of GAE/g by Annabelle *et al*. (2015), 1.80 mg GAE/g TPC in taro by Isabelle *et al*. (2010) and 78.33mg GAE/100g by Alcantara *et al*. (2013) were reported in literatures. Taro also composed of the widest range of flavonoids, with very high concentrations (up to 326 mg/100 g dry weight), but their individual identification was not conducted at the time (Lebot *et al*., 2018). Total flavonoid contents of about 64.23mg catechin eq /100g of taro were also reported by Alcantara *et al*. (2013). Thus, taro corm is considerable source for different bioactive compound possessing antioxidant activities.

2.4.4. Antioxidant capacity of taro

The polyphenolic compound such as flavonoid and non-flavonoid compounds present in taro corm are shown to have antioxidant capacity as measured by DPPH, FRAP as well as other assay methods (Baiao *et al*., 2017). After detail investigation of different antioxidant compounds and antioxidant tests using different assays, Kumar *et al*. (2017) concluded that the taro flour may have potential health benefits attributed to presence of different natural antioxidants. Taro is also reported as food with high antioxidant potential as study of phenolic compound and free radical scavenging capacity test indicated in previous study (Simsek *et al*., 2015)

2.4.4.1. 2, 2-Diphenyl-1- Picrylhydrazyl (DPPH) scavenging

There are different assays methods for determination of radical scavenging capacity of extracts of antioxidant compounds of which DPPH assay is easy, reliable and mostly utilized

one (Aksoy *et al*., 2013). As the author further elaborated, DPPH is a stable radical that does not disintegrated in water, methanol, or ethanol. This free radical scavenging test method depends on the capability of antioxidant compounds present in the extract to lose hydrogen and the structural conformation of these components (Fukumoto *et al*., 2000). The DPPH free radical therefore can easily receive the hydrogen from antioxidant molecules and become stable molecule. DPPH radical also have the ability to bind hydrogen and thus considered to have a radical scavenging property. A solution of DPPH radicals prepared in methanol is converted into DPPH-H (diphenylhydrazine) molecules in the presence of an antioxidant compounds as a result of which discoloration happens when quantity of DPPH radicals decrease in the solution. The discoloration of the DPPH is therefore the indication for radical scavenging capacity of the extract.

$$DPPH^{\circ} + A\text{-}H \rightarrow DPPH\text{-}H + A^{\circ}$$

Taro extracts have good antioxidant capacity as demonstrated by DPPH inhibition assay, which was shown to increase with the total phenolic content within the extract (Agyare *et al*., 2016). These authors further found the highest DPPH inhibition of 19.35 ± 0.82 % by *C. esculenta* corm extracts at the maximum concentration of 200µg/mL, suggesting that DPPH radical scavenging capacity of extracts depends on concentration level. As it was elaborated by these authors, DPPH radical scavenging activity of *C. esculenta* corm extract was found to be 74.34 ± 12.17µg/mL in terms of IC50 values. However, the standard ascorbic acid showed the lower IC50 value of about 9.23µg/mL indicating higher antioxidant capacity. This is confirming the fact that lower IC50 value corresponds to higher antioxidant capacity and vice-versa.

2.4.4.2.Ferric reducing power (FRAP)

The ferric reducing antioxidant power (FRAP) assay is among the different methods which have been developed for the evaluation of antioxidants capacity (Hernández-Rodríguez *et al*., 2007). According to these authors, it is the direct method of antioxidant capacity test which is a relatively simple, quick, and inexpensive. The FRAP is used for measuring the total antioxidant activity of reductive (electron donating) antioxidants in a test sample. The FRAP

assay uses the reduction of ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}) as the signal, or indicator reaction and this is tied to a color change in the solution. A wide range of sample types including food sample, medicine and other biological materials can be tested by the assay, and it can be used effectively with little specialized equipment, in a semi-automated version using a micro plate reader (Benzie and Malegaddi 2018).

The FRAP value of taro corm extract was found to be 516.6 +7.27 μM Fe(II)/g while it was 8666 +7.22 and 8333.7.44 μMFe(II)/g for butylated hydroxyl-toluene and butylated hydroxyl-anisole, respectively (Kasote *et al*., 2011). The report by Kumar *et al*. (2016) under the optimum conditions of evaluation indicated that the value of FRAP for taro corm extract was 63.78 mg BHT Eq/100 g. This may be an indication that the taro corms posses antioxidant capacity owing to the presence of different polyphenolic compounds.

2.5. Anti-nutritional factors and toxic components in taro

Anti-nutritional factors are those compounds in plant based foods responsible for reduction of nutrient utilization, thus contributing to impaired digestion, absorption and gastrointestinal and metabolic performance in general (Arendt *et al*., 2013). Several anti-nutritional factors have been found in taro, such as oxalate, tannins, alkaloid, phytate and protease inhibitors, trypsin inhibitor, mucilage and saponins (McEwan *et al*. 2008). Extensive research has proven that these compounds can exert a negative effect on human health including inhibition of protein digestion, animal growth, and absorption of mineral (Bradbury *et al*., 1990, Agwunobi *et al*., 2002, Omoruyi *et al*., 2007, Rao *et al*., 2010). Therefore, taro corms should be properly processed to eliminate or reduce the anti-nutritive effects and anti-nutritional factors to acceptable limits before consumption (Bradbury *et al*., 1995, Bhandari *et al*., 2004).

Oxalate was the predominant toxic anti-nutritional factor in taro (Abdulrashid *et al*., 2009). Anti-nutritional factors do not occur freely but combine with food components to form complexes. Phytate and oxalate combine with phosphorus and calcium, respectively to form complexes and render them unavailable for absorption (Otegbayo *et al*., 2018). On the other hand, anti-nutritional factors may serve as defensive mechanism against pests and diseases as elaborated in the above literature. For instance, oxalates

involve in defense mechanism against pests and diseases and a storage reserve for calcium in plant (Agwunobi *et al*., 2002).

Table 2.5 Levels of anti-nutritional factors (mg/100 g) in raw sundried taro corm flour

Antinutitional factors (mg/100 g)	Abdulrashid *et al*. (2009)	Adane *et al*. (2009)	McEwan *et al*. 2008
Oxalate	45.30+0.02	243.06- 265.88	7-14
Phytate	1.75 +0.20	115.43- 135.28	220-320
Tannin	1.78+0.01	47.69- 59.92	0.001-0.0051
Alkaloid	-	-	14-22

2.5.1. Oxalic acid

The *oxalis* in plant, commonly called as wood sorrel gave rise to oxalic acid (chemical formula HOOC-COOH). Oxalic acid is an organic acid which has been found to be widely distributed in plants (McEwan *et al*., 2008). Oxalic acids have the capacity to bind with different minerals calcium, magnesium, sodium and potassium hindering their bioavailability (McEwan *et al*., 2008).

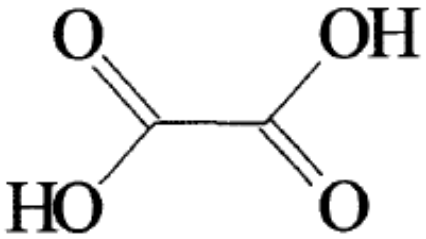


Figure 2.2: Structure of oxalic acid

(McEwan *et al*., 2008).

This is one the major anti-nutritional factors limiting the utilization of taro. The presence of oxalates in taro may be a factor which imparts acrid taste or cause irritation when raw or unprocessed foods from taro are eaten. This acridity phenomenon causes the irritation and swelling in mouth and throat (Bhandari *et al*., 2004). High oxalate concentrations in the leaves and corms of taro 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). Oxalic acid and

its salts can decrease calcium absorption and also aiding the formation of kidney stones; and hence have deleterious effects on human nutrition and health (Bhandari *et al*., 2004).

Almost all parts of most taro varieties are reported to contain calcium oxalate. Processing methods including boiling, soaking and drying can reduce the soluble oxalate content as literatures across the globe reported. Overall, boiling the taro leaves was shown to be an effective way of reducing the soluble oxalate content of the tissue (Adane *et al*., 2013). In the study by Alcantara *et al*. (2013), oxalate content of taro corm flour as high as156.33 mg/100g was reported.

2.5.2. Phytates

Phytic acid, common in the plant kingdom is found mainly in mature seeds such as legumes, fruits, vegetables and cereal grains and can binds proteins, starch and metallic cations (Ca, Fe, K, Mg, Mn and Zn) and forms a mixed salt called phytin or phytate and reduce bioavailability (McEwan *et al*., 2008). Phytic acid (PA, $InsP_{6,}$ hexaphosphate of myo-inositol) is known to be contained in different parts of plants both seeds, roots and tuber. It ranges from one to five percent weight of the cereals and serves as the chief storage form of phosphorus. As opposed to its nature as anti-nutrient, it has an important role as an antioxidant by forming complex with iron and thereby reducing free radical generation and the peroxidation of membranes, and may also act as an anti-carcinogen, providing protection against colon cancer (Charles *et al*., 2005).

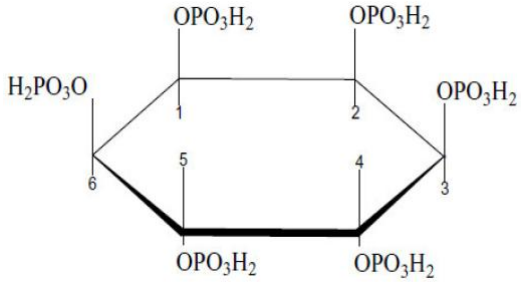


Figure 2.3: Molecular structure of phytate

(Shi *et al*., 2004)

Consumption of food containing high quantity of phytate decreases the bioavailability of minerals, especially Ca and Zn. Phytic acid markedly reduces the bioavailabilty of Ca and forms Ca-phyate complex and this complex in turn inhibit the absorption of Fe and Zn (Plaami *et al*., 1997). Protein digestibility is also decreased with phytic acids as it forms complex and interfering with enzymes such as trypsin and pepsin also (Reddy *et al*., 1994). It may also affect starch digestibility by combining with digestive enzymes or binding minerals such as Ca, which catalyze or cofactors in enzyme activity (Plaami *et al*., 1997). According to the study by Alcantara *et al*. (2013), phytate content of taro corm flour about 85.47 mg/100g was reported.

2.5.3. Tannins

Tannins are a high molecular weight polyphenolic compounds which can either be hydrolysable or condensed tannins in nature. Tannins are naturally occurring water-soluble polyphenolic compounds and possess the ability to precipitate proteins by binding and making complex with in aqueous solutions (Gilani *et al*., 2005). The hydrolyzable tannins are readily hydrolyzed by acids, alkalis, or some enzymes, yielding glucose or some other polyhydroxy alcohol and gallic acid or some related phenolic acids (Gilani *et al*., 2005). These authors elaborated that condensed tannins on the other hand are polymerized products of flavan-3-ol (catechin) and flavan-3,4-diol or a mixture of these, are also referred to as flavolans or procyanidins, and they are resistant to hydrolysis.

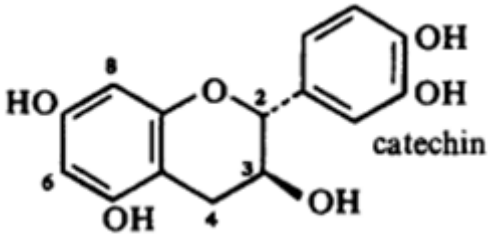


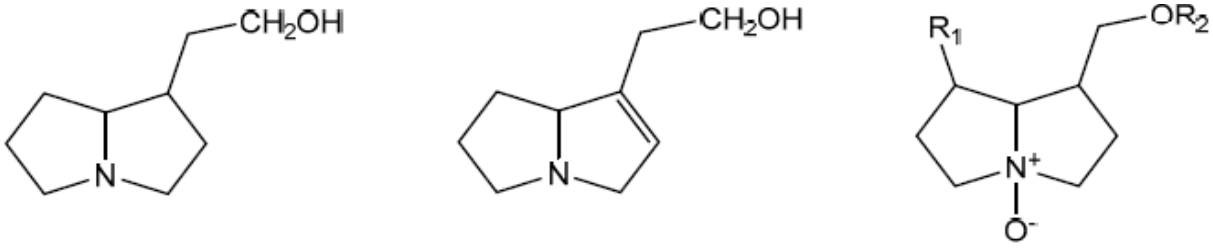
Figure 2.4: Structure of condensed tannin

Haslam 1977

From the two types of tannins, condensed tannins are more resistant to microbial decomposition than hydrolysable tannins (Kumari *et al*., 2012). As it is further stated in this journal, hydrolysable tannins are present only in trace amounts in commonly consumed plant foods than condensed tannins. So, condensed tannins are of more concern due to their anti-nutritional effects in food. It can form insoluble complexes with protein and iron and thus affecting the utilization of these food components. The report by Adane *et al*. (2013) indicate that the condensed tannin content of raw taro corm were between 47.69 and 59.91mg/100g. However, Olajide *et al*. (2011) reported as high condensed tannin as 280mg/100g in taro corm sample.

2.5.4. Alkaloids

Alkaloids as reported by Kukula-Koch *et al*. (2017) were established to be present in both the plant kingdom, and even in animals, including humans, marine organisms, fungi, and other microorganisms though still plants are perceived as the main natural sources of these plentiful natural products. Alkaloids are one of the different constituents of roots and tubers crops (Rong *et al*., 2016). According to Azene (2017), alkaloids are among the common anti-nutritional constituents composed in roots and tubers including taro. McEwan *et al*. (2008) reported alkaloid range between 14mg/100g and 22mg/100g in taro corms flour.



1,2-Dihydro 1,2-Unsaturated *N*-oxide

Figure 2.5: Structure of an alkaloid and its different R1 and R2 correspond and its different forms

(Moreira *et al*., 2018)

2.6. Processing and trends of taro utilization in food applications

Taros are fried, blanched, steamed, stewed, roasted, baked, or boiled before consumption or for the preparation of various dishes and is recommended for gastric patient and its flour is good in the preparation of baby food due to its high digestibility (McEwan *et al*. 2008). More modern ways of boiling and steaming, or baking taro in oven are also emerging in different parts of the world (Soudy *et al*., 2010). As elaborated farther in this literature, taro retains its food value if cooked whole as it contains anti-nutritional factors and thus these processes are effective in improving digestibility, increasing nutrient bioavailability and also minimizing anti-nutritional factors.

It may be obvious that processing methods of taro corm can affect the proximate composition, mineral content, phytochemical components and anti-nutrient contents similar to other food processing. Therefore, the combination of cooking time temperature program is necessary to preserves the nutrients and deactivates the anti-nutritional factors. On the other hand, according to Soudy *et al*. (2010), cooking increases antioxidant activity, crude fat, crude protein and crude fiber contents and thus cooking substantially can used in the management of non communicable illness such as obesity, heart disease, blood pressure, diabetes, cancer and gastrointestinal disorders because of the sufficient fiber content.

Traditionally, taro corms are consumed by just boiling, drained water off and served as a snack in different parts of Ethiopia like Gambella, Maji (Umeta *et al.*, 2005). According to these authors, processed forms of taro are not very common in Ethiopia but, people in Ethiopia are eating taro corm as boiled. Despite this fact, there are emerging activities related to production of flour from taro for partially substituting it into different traditional food products (traditional breads for example) (EKN Learning Event 2015). This will increase production and utilization as a functional food which will not only reduce the problem of chronic diseases now prevailing in almost all countries but also encourage the industry and farmers to produce value-added or healthy products from these underutilized crops (Trinidad *et al*., 2010).

2.7.Taro flour

The flour from roots and tuber crops in general had the highest amount of resistant starch, phytochemicals, minerals and vitamins (Liu *et al*., 2006). Due to these and other chemical constituents, taro and other roots and tubers are potential crops to be processed into flour and used in development of numbers of products. Taro starches have the high viscosity and this would make them very useful in food applications where high thickening power is desired as well as the small particle size being useful for noodle or bread production (Liu *et al*., 2006). As recommended by Himeda *et al.* (2014), for the taro flour to be prepared, the taro tubers will first be sliced and dried in air convection at 40 ± 2 °C until the moisture content is low enough so that the sliced corm will be brittle enough for grinding. The dried slices were first hammer milled (Culatti polymix, France) to pass through a 200 μm screen.

2.7.1. Functional properties of taro flour

Functional properties are essential quality indicator for consideration of given flour in the baked food products as they affect different sensory and physical characteristics of the food (Olaoye 2017). These properties include water absorption capacity, water solubility index, oil absorption capacity and etc. that can have direct influence on the usability and the quality of products made from the flour. These functional properties are important with respect to food recipes and industrial applications. Therefore, before considerations of roots and tuber crops as potential source for flour production, characterization of functional properties, physicochemical properties and chemical composition is necessary. Functional properties such as swelling, solubility and digestibility are reported to be dependent on factors like granule size (Moorthy, 2002).

2.7.1.1.Bulk density (BD)

Bulk density according to Yenenesh (2016) is indicator of the behavior of a product in food formulations and lower BD is good in weaning formulation (Chandi *et al*., 2007, Mohamed *et al*., 2009) and high BD for suitability in baked food preparations. BD is also very important parameter in determining the packaging requirement, and material handling in the food

industry is determined by the particle size and density of the flour and varies with the fineness of the particles (Mohamed *et al*., 2009, Adeleke *et al*., 2010). Taro flour is suggested for its suitability to be used as thickener in food products as its BD as high as 0.689 g/mL help to reduce paste thickness which is an important factor in convalescent and child feeding (Kaushal *et al*., 2012).

2.7.1.2.Water absorption capacity (WAC)

Water absorption capacity is the water retained by a food product following filtration and application of mild pressure of centrifugation (Falade *et al*., 2015). According to these authors, water absorption capacity of flour enables the processor to add more water during food preparation thereby improving handling characteristics. The higher water absorption capacity of flour has contribution to maintain the freshness of products of the respective flour such as bread. The high water absorption capacities of the flours indicate that the flours can be used as a soup thickener. The ability of flour to absorb water is a very important property of flours used in food preparation (Mbofung *et al*., 2006) and is sometimes attributed to protein content. The WAC is an important functional property required in food formulations especially those involving dough handling and plays an important role in dough functionality; improve yield and consistency (Osundahusi *et al*., 2003, Udensi, *et al.*, 2008). Hossain (2016) reported that, the flour obtained from the taro corm exhibited higher water absorption capacity (WAC) 290 % than that for wheat flour 130 %.

2.7.1.3.Oil absorption capacity (OAC)

Oil absorption capacity as explained by Falade *et al*. (2015) is the reflection of the emulsifying capacity and the amount of oil that can be picked up by a sample during frying, and is a highly desirable characteristic in products such as mayonnaise prepared from flour. The higher oil absorption capacity (OAC) for taro flour than wheat flour was observed and reported by Hossain (2016). According to Sharma *et al*. (2016) also, raw taro flour has high oil absorption capacities. The higher capacity of taro flour to absorb oil may show that taro can improve the properties of the other flour during formulation of flours.

2.7.1.4.Water solubility Index (WSI)

Water solubility index (WSI) is a flour parameter that is used as a measure for starch degradation; that means lower WSI indicates that there is minor degradation of starch and such condition leads to less numbers of soluble molecules in the flour (Hernandez-Diaz *et al.*, 2007). The water solubility index is an indicator of degree of starch gelatinization and was shown to increase with increase in proportion of taro in the different flour blend (Sharma *et al*., 2016). As it was reported by Hossain (2016), taro flour has higher water solubility index 18.5% as compared to that of wheat flour (15.5%). It is also other good properties of taro flour to have higher solubility in water.

2.7.1.5.Swelling power

The swelling power is a measure of hydration capacity of starch and indicates the water holding capacity of starch (Sharma *et al*., 2016). As it is explained by these authors, swelling power and solubility are a function of pH. The effects of pH and heating temperature on their swelling powers and solubility shows that heat-moisture treated and chemically modified starches have lower swelling power (at 95°C) than that of isolated starch. Swelling power is a measure of hydration capacity, because the determination is a weight measure of swollen starch granules and their occluded water (Falade *et al*., 2015). As it is explained by these authors, the eating quality the food is often connected with water retention in the swollen starch granules. According to Eriksson (2014), *s*welling power can be expressed as the weight of sediment per gram of starch, is defined as the maximum increase in volume and weight that the starch undergoes when heating in excess water. The swelling power of a flour is related to the digestibility in such a way that the low swelling power will facilitate the rate of digestion of the product and consequently recommended for the aged people (Lukuman *et al*., 2018).

2.7.1.6.Dispersibility

Dispersibility is a measure of reconstitution of flour or starch in water, the higher the dispersibility, the better the sample reconstitutes in water (Adebowale *et al.,* 2011) and gives a fine constituent during mixing (Adebowale *et al*., 2011). The lower the dispersibility of flour

samples is probably the indication of the fact that the samples will have lump formation tendency during preparation (Oluwole *et al.*, 2016).

2.7.2. Bread from taro corm flour substituted wheat

Bakery products including breads have become very popular and consumed by people of all age groups across the world. Flour used in production of these baked products can be made from a wide variety of plant products. However, the vast majority is made from wheat. Dough made from wheat flour is particularly well suited to baking bread because of the fact that it contains a large amount of gluten, a substance composed of strong, elastic proteins. So, in case there is shortage of wheat, it necessitates the import from producing country which could lead to the raised price of bread product.

Ethiopia, like other most developing countries is the largest importer of American red winter wheat which implies that they are dependent on foreign country for their bread production (Lamrot 2018). On the other hand, incorporating novel flour sources like taro flour in cereal products is a recent trend to meet the shortage of wheat flour production, decrease the import of wheat and minimize the cost of cereal products (Ammar *et al.*, 2009*).* According to the authors, this will not only cost minimization, but also enhancing the use of the local underutilized crops.

Substitution of taro flour to wheat flour in bread making is an important opportunity toward utilization of this crop (Abera *et al*., 2017). According to the authors, good quality bread can be produced by blending wheat flour with taro corm flour in different proportion. However, as the proportion of taro increase, physical characteristics of the composite flour and the acceptability of bread decrease. According to Lamrot (2018), 20g taro flour substitution with 100g wheat flour in bread making did not adversely affect the quality properties of the bread and produce bread comparable to that produced from wheat flour. Ammar *et al*. (2009) on the other hand conclude 10% taro flour substitution produces bread similar to the control (wheat bread). Thus, these reports are indication for possible partial substitution of taro flour in baked products including bread.

According to Ammar *et al. (*2009), an increase of the taro flour level resulted in decreasing in the crude protein and ether extract while, ash, total carbohydrates and fiber contents increased. Similarly, increase of taro flour in blending ratio increased the proximate values like carbohydrate, the crude fiber and the ash contents whereas the protein content decreased significantly (Lamrot 2018). Therefore, substitution of wheat flour by taro corm flour in bread making can contribute to cost optimization of bread without much effect on proximate composition of bread.

2.8. Summary

Taro is one of the most important perennial roots and tuber crops, widely produced for its underground corms and consumed in different parts of the world. It is a major carbohydrate source, mainly starch and other nutrients such as minerals, fiber, vitamins. Taro is also rich in non nutritional components called phytochemicals which may offer additional health promoting benefits. However, taro has also been found to contain anti-nutritional factors that can jeopardize the wider utilization of its nutrients especially, minerals, protein and starch, and thus compromising the nutritional quality of the crop. Taro flour has great potentials for use in food formulations including baked products such as bread, and this has been reported from elsewhere in different parts of the world.

In the past, flours of processed taro varieties were investigated for their nutrients and antinutrient constituents, and its bread making performance through partial replacement of other flour such as wheat flour. However, limited studies were undertaken in characterization of some taro varieties from Ethiopian for some nutritional quality characteristics as affected by different processing methods. Despite a good number of literature sources show that taro flour is used in a number of food preparations, there are no studies conducted on bread making potentials of flours of taro varieties grown in Ethiopia. Thus, in this MSc. thesis, studies on bread making potentials of flours from different taro varieties grown in Ethiopia were reported.

3. MATERIALS AND METHODS

3.1. Materials

Two taro varieties (Danu and Kihaque) and four taro accessions (Ac-5, Ac -12, Ac-18, and Ac-21) harvested during 2019 harvesting season were obtained from Jimma Agricultural Research Center (JARC) from the same research farm; cultivated under the same agronomic condition and management practices for this study. A Kihaque variety from the two varieties was found to be superior in most of its nutritional attributes analyzed and thus its flour was used in composite flour formulation for bread making. All the analyses of the sample were made in triplicate. All the chemicals used in the experiment were of standard quality.

Figure 3.6: Taro corms (Author's collection during sample preparation)

3.2.Processing of taro corms into flour

Taro corms were processed into flour using the procedure described in a previous study (Kaur *et al.*, 2013). Physically damaged and immature corms were removed and sorted to uniform size. The corms were thoroughly washed to remove any dirt such as soil and minimize surface micro-organisms or other impurities, peeled and sliced in to 0.5 cm thinness to make it ready for flour preparation. The slices were then placed on a stainless steel tray and sun-dried (*ca*.

25 °C) for three days until the slice was brittle enough for milling and the moisture content is below 11% to a constant weight. The dry taro slices were milled with a laboratory scale grinder (High speed universal disintegrator FW 100, China). The flour was sieved through a 0.425 mm mesh sieve to get uniform flour sample which was done twice to get fine flour. The flour was then packed in polyethylene plastic bags and stored at 4°C until use.

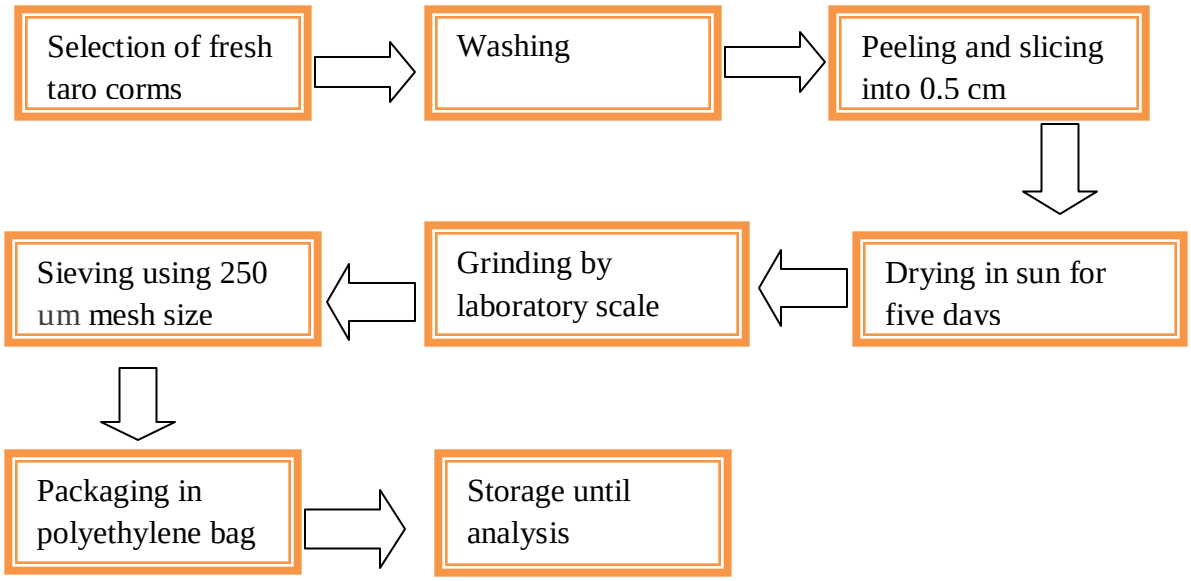


Figure 3.7: Flow sheet for processing of taro corms into flour

(Kaur *et al.*, 2013).

3.3. Analyses nutritional composition of taro

3.3.1. Proximate analysis

3.3.1.1.Determination of moisture content

The moisture content of the taro flour was determined following AOAC (2000) using the official method 925.09. Taro flour samples (5 g) were weighed on a pre-weighed clean and dry aluminum dish. The dish were then placed in the oven (Oven model DHG-9203 (A)) at 105 ^{o}C for three hours and then taken out and cooled in desiccators and re-weighed. These steps were repeated until the weight change becomes constant. Once a constant weight is attained, the moisture content was estimated gravimetrically.

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1} X100\%$$

Where,

W1 = initial weight of sample; W2 = dried weight of sample

3.3.1.2. Determination of crude protein content

The crude protein content was determined according to AOAC (2000) using the official method 979.09. Flour sample (1 g) was weighed and added to the digestion flask and 6 mL of concentrated sulfuric acid and concentrated orthophosphuric acid and about 3g of K_2SO_4 and $CuSO_4$ catalyst mixture were also added and then were exposed to heating temperature of about 370°C in order to allow digestion for an hour. Then, distillation will took place in kjeldhal apparatus (VELP SCIENTIFICA UDK 159 Automatic distillation and titration) by adding 25 mL of 40% NaOH and using 25 mL of boric acid with 10 drops of indicator solution. After distillation, the distillate was titrated with standardized solution of 0.1N HCl till reddish color developed within the kjeldhal apparatus. The crude protein content was estimated using the formula for protein determination.

$$\text{Kjeldhal nitrogen (N \%)} = \frac{(V2-V1)\ X\ N\ X\ 0.014007\ X\ 100}{W}$$

V1= Volume in mL of the standard sulfuric acid used in the titration for the blank Determination

V2=Volume in mL of the standard sulphuric acid solution used in the titration of the test material

N= Normality of the standard sulphuric acid

W= weight in grams of test material

The protein was converted with the following formula:

$$\text{Crude protein content} = \text{total nitrogen X } 6.25$$

3.3.1.3. Determination of crude fat content

The crude fat content was determined by soxhlet fat extraction according to AOAC (2000) using official method No 4.5.01. A 5 g of dried sample of taro flour was added to well cleaned and dried thimble and the thimble was covered with fat free cotton at the bottom and top and was placed in the extraction chamber. Extraction took place using soxlhet extractor (SZC-C Fat Determinator shanghai xianjian instruments co., ltd) for at least 4hrs according to

AOAC (2000) official method 4.5.01. Then finally, after extraction the solvent is removed by means of a rotary evaporator, yielding the extracted compound and the crude fat content was determined by the formula given below:

$$Crude\ fat\ (\%) = \frac{M2-M1}{M} X100\%$$

Where M_2=mass of flask and lipid extracted; M_1=mass of dried flask; M = weight of sample on dry basis

3.3.1.4. Determination of crude fiber content

The crude fiber content was determined using the method of AOAC (2000) official method 962.09 by fiber diterminator (SLQ-6A Crude fiber Determinator). About 1.6g weighed sample (W) was transferred into a 600 mL beaker and about 200 mL 1.25% sulfuric acid was added and boiled for 30 minutes. Recording took place by placing a watch glass over the mouth of the beaker. After 30 minutes heating by gently keeping the level constant with distilled water, 20 mL 28% KOH was added and boiled gently again for another 30 minutes. Then, washing 1% sulfuric acid and NaOH solution was conducted. After, filterion, dried in an electric oven (Oven model DHG-9203 (A)) at 130 °C for 2hrs. Furthermore, it was cooled at room temperature for 30 minutes in a desiccators and weighed (W_1), then transferred the crucibles to be ignited in muffle furnace (Carbolite Parsons Lane, Hope, serial No 20-401898 England.) for 30 minute ashing at 550 °C. Then, the sample was taken from muffle furnace and was cooled again in desiccators and reweighed (W_2).

The crude fiber content was finally determined by using the formula given bellow:

$$\text{Crude fiber content (mg/100)} = \frac{(W1-W2)(100-m)}{W}$$

Where, W_1= crucible weight after drying; W_2= crucible weight after ashing; W= dry weight of original sample; M= % moisture of the sample

3.3.1.5. Determination of total ash content

The ash content was determined by AOAC (2000) method 923.03. The crucible dish used for the ashing was washed by dilute hydrochloric acid while boiling. Then, it was washed with

distilled and de-mineralized water respectively. Then dried at 120 (°C) in an oven and ignited at 550^0C in (Carbolite Parsons Lane, Hope, serial No 20-401898 England) furnace for 3 hour. The dish was remove from furnace and cooled in desiccators to be weighed. The mass of the dish was then measured using analytical balance (ARZ140, N315, SNR=1203290469, USA) and the reading of the balance was recorded as (M_1). About 2.5 gm of sample powder was weighed and added to the crucible dish and this reading was recorded as (M_2).The sample was first charred at 120^0C on hot plate (Wagtech, UK, hot plate SH3), until the whole content becomes carbonized. Then the sample was taken to the furnace (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) kept overnight at 550°C to be ignited until whitish color appears. The sample was removed from the furnace and cooled in desiccators and weighed which was designated as (M_3) and the ash content was calculated based on the equation below:

$$\text{Ash } (\%) = \frac{\text{M3}-\text{M1}}{\text{M2}-\text{M1}} * 100\%$$

M1=mass of the dried dish; M2=mass of the dish and the sample; M3=mass of the dish and the ash

3.3.1.6. Determination of utilizable carbohydrate content

The carbohydrate contents were determined by deference method by deducting the sum values of other parameters (dry basis) from 100. Therefore, the formula is:

$$\text{Utilizable carbohydrate } (\%) = 100 - (\%\ \text{C. protein} + \%\ \text{C. fat} + \text{C fibre} + \%\ \text{ash})$$

3.3.2. Total energy in kilo calories

Total energy content in each of taro flour and the composite bread was determined mathematically according to the FAO recommendation from the chemical composition of the taro. The quantities for the three energy yielding nutrients (Fat, protein and carbohydrate) was multiplied by their respective Atwater conversion factors using the formulae indicated below for both the varieties of taro and bread flour samples (FAO, 2003):

$$\text{Total energy (Kcal)} = (9\ \text{fat content} + 4\ \text{protein content} + 4\ \text{carbohydrate Content})$$

3.3.3. Determination of minerals content

Mineral contents (Ca, Mg, and Fe) of the samples were determined by dry ashing of the sample (2.5g) in a muffle furnace. Atomic absorption spectrometer (AAS) (AA-6200 ATOMIC ABSORPTION FLAME EMISSION SPECTROPHOTOMETER, SHIMADZU) was used to measure Ca, Mg and Fe elements, while Na and K were analyzed by the flame emission spectrophotometer (FES) (CORNING Photometer 410) according to the AOAC (2000) Official Method 985.35. A calibration curve (indicated in annex) was generated for all minerals analyzed by AAS using a working standard series solution of 0, 0.5, 1 and 2 mg/L for all minerals. The content of all minerals: Ca, Mg, Fe, Na, and K were determined from their respective emission measurement at wavelengths of 422.7 nm, 239.6 nm, 285.2 nm 589.0nm; and 766.5 nm, respectively from the calibration curve of each standard.

$$\text{Concentration } \left(\frac{\text{mg}}{100\text{g}}\right) = \frac{(\text{a} - \text{b})\text{X V}}{10 \text{ X W}}$$

Where; a = concentration in ppm of sample solution; b = concentration in ppm of blank solution; V = volume in mL of the extract; W = weight of sample

Total phosphorous determination

The sample solutions prepared for mineral determination were used for phosphorous determination. One mL of the clear extract (sample solution prepared for mineral determination) was diluted into 50 mL with deionized water. Five mL of the sample solution was added into test tube. Half mL of molybdate and 0.20 mL aminonaphtholsulphonic acid were added into the test tube (sample solution) and mixed thoroughly step by step. The solution was allowed to stand for 10 minutes.

Standard curve preparation

Six series of working standard phosphorous solutions (0, 1, 2, 3, 4 and 5 µg/ mL) were prepared by appropriate dilution of the phosphorous stock solution (1000 µg P/ mL of KH_2PO_4) with deionized water using 10 mL volumetric flask. The instrument was calibrated to zero using distilled and deionized water. The absorbance of the standard sample, blank and

sample solution were measured at 660 nm using UV-VIS spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL No 124-244). Calibration curve (concentration versus absorbance indicated in annex) using the prepared standard solutions was prepared. And the concentration of phosphorus in the sample solution was determined using the following equation:

$$P\left(\frac{mg}{100g}\right) = \frac{\text{Sample absorbance} - \text{blank absorbance X Dilution factor}}{\text{Slope X Wt of sample}}$$

3.3.4. Determination of anti nutritional factors

3.3.4.1. Determination of oxalate content

The oxalate contents of taro corm flour were determined using the method by Iwuoha *et al*., 1995 later modified and used by Adane *et al*. (2013). In this method, three important steps involved were followed one after the other as described below: digestion, oxalate precipitation and permanganate titration.

Digestion

Taro flour sample (4 g) was suspended in 190-mLof distilled water contained in 250 mL conical (Erlenmeyer) flask; 10 mL of 6 M HCl was added and the suspension was digested at 100°C for 2hrs followed by cooling, and then solution was made up to 250 mL mark using distilled water and filtered in to another flask.

Oxalate precipitation

Duplicate portions of 125 mL of the filtrate were measured into a beaker and four drops of methyl red indicator was added, followed by the drop wise addition of concentrated NH_4OH solution until the test solution changed from its salmon pink color to a faint yellow color (pH 4-4.5). Each portion was heated to 90°C, cooled and filtered to remove precipitate containing ferrous ion. The filtrate was heated again to 90°C and 10 mL of 5% $CaCl_2$ solution was added while being stirred constantly. After heating, it was cooled and left overnight at 5°C.

Thereafter, the solution was centrifuged at a speed of 2500 rpm for 5 min. The supernatant was decanted and the precipitate completely dissolved in 10 mLof 20% (v/v) H_2SO_4 solution.

Permanganate titration

At this step, the total filtrate resulting from digestion of 4 g of taro flour was made up to 300 mL. Aliquots of 125 mL of the filtrate was heated until near-boiling, and then titrated against 0.079 M standardized KMnO4 solutions to a faint pink color which persisted for 30 s. The calcium oxalate content was calculated using the formula given below:

$$\text{Oxalates}\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{\text{T X (Vmeq)X DF X105}}{\text{(ME)X Wf}}$$

Where,

T is the titre of KMnO4 (mg/100 g), (mL),

Vmeq is the volume-mass equivalent in which 1 cm^3 of 0.079 M $KMnO_4$ solution is equivalent to 0.00225 g anhydrous oxalic acid),

DF is the dilution factor VTA (where V is the total volume of filtrate (300 mL) and A is the aliquot used (125 mL),

ME is the molar equivalent of KMnO4 in oxalate (KMnO4 redox reaction and wf is the mass of flour used.

3.3.4.2.Determination of phytate content

The phytate content was determined as described in Vaintraub *et al*. (1988). Flour sample (0.5 g) was extracted with 10 mL 2.4% HCl for 1 h at ambient temperature and centrifuged (Sigma 2-16KC) (3000 rpm) for 30 min. To a clear supernatant or extract (3 mL), 1 mL of Wade reagent (0.03% solution of $FeC1_3.6H_2O$ containing 0.3% sulfosalicylic acid in water) was added, homogenized and the mixtures were centrifuged at 3000rpm for 10 min. The absorbance was measured at 500 nm using UV-VIS spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL No 124-244). A series of working standard solutions (5–40 mg/mL, R^2 =0.9532) were prepared from stock solution (0.1814g/50-mL = 3000 µg phytate/mL) of pure phytic acid (≥ 90% phosphorus) for calibration curve (indicated in annex). Standards (3 mL) were pipetted into 15 mL falcon tubes to which 3 mL

of deionized water was added. To each tube, the wade reagent (1 mL) was added, and the solution was mixed using a vortex mixer for 5 s. The mixture was further centrifuged for 10 min and the absorbance of the solution was read at 500 nm by using water as a blank. The absorbance for phytate concentration was calculated from the difference between the absorbance of the blank (3 mL of water+1 mL Wade reagent) and that of assayed sample as shown below. By Plotting the calibration curve (absorbance vs. concentration) and one can find out the slope and intercept. Final results were expressed as milligram of phytic acid per 100 gram of flour dry matter (mg/ 100, dm).

$$\text{Phytate mg/100g} = \frac{(A-I)X\ 10}{S\ X\ D\ X\ W}$$ Where,

A = absorbance; I = intercept; S = slope; D = density; W = weight of sample taken

3.3.4.3. Determination of condensed tannin content

The condensed tannin contents of taro flour samples were measured following the method reported by Maxson and Rooney (1972) and later modified and used by Akalu *et al*. (2017) using Vanillin-HCl reagent that was prepared by dissolving 2 g vanillin in 4% acidified methanol. Flour samples (*ca*. 1 g) were weighed in a screw capped test tube and extracted with 10 mL of 1% HCl in methanol for 24 h with a mechanical shaker at room temperature, centrifuged (1000 rpm for 5 min). A clear supernatant (1 mL) was transferred into clean falcon tubes, mixed with 5 mL of vanillin-HCl reagent (equal volumes of 8% concentrated HCI in methanol and 4% vanillin in methanol) and the mixture was allowed to stand until the completion of the reaction. After 20 min, the absorbance was read at 500 nm using UV-Visible spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL No 124-244). Blank solution (1 mL of extract + 5 mL of 1 % HCl without vanillin-HCl reagent) was used. Different D-Catechin concentrations (0, 12, 24, 36, 48, and 60 mg/100 g) to draw a standard curve indicated in annex ($y = 0.0054x + 0.0256$, $R^2 = 0.9955$). The results were expressed as catechin equivalents per 100 g flour on the dry weight basis using the formula given below.

$$\text{Tannin (mg/100g)} = \frac{\{(As-Ab)-I)\}}{S\ x\ D\ x\ W}$$ where,

A_s = Absorbance of sample; A_b = Absorbance of blank; I = Intercept, S = Slope; D = Density; W = Weight sample taken

3.3.4.4. Determination of alkaloid content

Total alkaloid content was determined by the method by Harborne (1973). Flour sample (5 g) was dispersed into a 250 mL beaker and extracted with 200 mL of 10% acetic acid in ethanol, after which it was covered and allowed to stand for 4 hr. The filtrate was concentrated on a water bath to one-quarter of the original volume. The alkaloid in the extract was further precipitated by drop-wise addition of concentrated ammonium hydroxide (NH_4OH) to the extract until the precipitation was completed. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide and then filtered on a pre weighed filter paper (W1). The final residue left on the filter paper was dried in a drying oven at 60 ^oC for 30 min and the weight of the precipitate and the filter paper was taken together (W2). Total alkaloid content in the flour sample was calculated gravimetrically as depicted below, and results were expressed in mg/100 g of the flour on a dry weight basis.

3.3.5. Determination of phytate:mineral molar ratio

Molar ratios of phytate:calcium (Phy:Ca), phytate:iron (Phy:Fe), phytate:zinc (Phy:Zn) and Phy*Ca:Zn as an indicative of intestinal mineral absorption (bioavailability) were calculated after dividing the mass of phytate and minerals with their molecular and atomic mass (phytate = 660g/mol; Fe = 56g/mol; Zn = 65g/mol; Ca = 40 g/mol) and dividing the molar ratio of phytate with the individual mineral molar ratio (Habtamu *et al*., 2018).

3.4. Phytochemical composition

3.4.1. Preparation of extract

Sample extracts were prepared based on the procedures outlined by Woldegiorgis *et al*. (2014). Taro flour sample (10 g) was extracted by homogenizing with 100 mL of methanol at 25 °C on mechanical shaker (ZHWY- 103B) for 24 hrs. The mixture was filtered through Whatman No. 4 paper and the supernatant was collected. The residues were re-extracted with 100 mL of methanol following the same procedure as described above. The extracts from the

first and second round extraction were pooled and evaporated to dryness at 40 °C using rotary evaporator (Stuart R3300). The dried pellets were re-dissolved in methanol at the concentration of 50 mg/mL and stored at 4 °C until use.

3.4.2. Determination of total phenolic content (TPC)

Total phenolic contents were measured using Folin-Ciocalteu reagent as described in Dewanto *et al*. (2002). Standards or aliquot of properly diluted extracts (1 mL) were mixed with 0.5 mL of distilled water and 0.125 mL of 10-fold diluted freshly made Folin–Ciocalteu reagent (Sigma-Aldrich, St. Louis, MO, USA). The mixtures were shaken and allowed to stand for 6 min at room temperature. Then, 1.25 mL of saturated sodium carbonate (Na_2CO) (7%, v/v) was added to the mixture, and the volume of the solution was adjusted with double-distilled water to a final volume of 3 mL. The mixtures were thoroughly mixed and the contents were incubated for 2 hrs in the dark at room temperature, and the absorbance at 760 nm was read using a spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL No 124-244) against the methanol blank. TPCs were calculated from the calibration curve (in the annex) of gallic acid with 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1mg/mL and expressed as milligrams of gallic acid equivalents (GAE) per gram of the flour on dry weight (mg GAE/g dm).

3.4.3. Determination of total flavonoid content (TFC)

TFC was determined using the aluminum chloride colorimetric assay using catechin as a reference standard as described in Dewanto *et al*. (2002). This method based on the formation of a complex flavonoid-aluminum having the maximum absorbance at 510 nm. Standards solution of (+)-catechin or aliquots of diluted sample extracts were mixed with 75 mL of $NaNO_2$ solution (5%, w/v) and distilled water (1 mL) and vortex mixed. After 6 min, 0.15 mL $AlCl_3$ (10%) was added, and the incubation of the mixture was continued for another 5 min. The reactions were terminated by adding 0.5 mL of NaOH (1 M) and the contents were allowed to stand for 15 min in the dark at room temperature. The final volume was adjusted to 2.5 mL with distilled water and mixed thoroughly. The absorbance was measured spectrophotometrically (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL No

124-244) at 510 nm against a blank. The total flavonoid contents were derived from the calibration curve indicated in the annex (y= 0.01x + 0.0244, R^2 = 0.9909) of (+)-catechin (0 to 400 mg/mL) and expressed in mg catechin equivalents per gram of flour on dry matter basis (mg CE/g dm).

3.4.4. Determination of ß-carotene content

Total ß-carotene content was determined following a previously reported method of Sadler *et al*. (1990). Flour sample (*ca*. 1 g) was mixed with of 1gram $CaCl_2.2H_2O$ and 50 mL extraction solvent (50% hexane, 25% acetone, and 25% ethanol, containing 0.1% BHT) and shaken 30 min at ambient temperature. Then, 15 mL of distilled water was added and the solution was frequently shaken for a further 15 min. The organic phase, containing the ß-carotene was separated from the water phase, using a separation funnel, and filtered using Whatman filter paper No.1. The extraction was carried out under subdued light to avoid degradation of carotenoids. β -carotene was estimated from standard curve of beta carotene standard (Sigma-Aldrich, St. Louis, MO, USA) dissolved in the same solvent combination used for sample extraction. Stock solution of beta carotene standard was prepared by accurately weighing 0.01g beta-carotene standard and dissolved in 20 mL solvent. The solvent was similar to that of used to extract of the samples (50 % hexane, 25 % acetone, and 25 % ethanol) and made the volume to 100 mL using the same solvent. A working standard series of 0, 2, 3, 4 and 5mL were added in to 100mL flask and diluted to give 0, 0.1, 0.2, 0.4, and 0.8 mg/L of beta carotene standard, and the absorbance was read using a double beam UV-Vis spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL No 124-244) at 450nm wavelength. Data obtained from this reading was used to generate a calibration curve which is indicated in the annex part of this document. The β-carotene content was calculated by subtracting the blank absorbance from the sample absorbance using the calibration equation of the standard curve shown below:

$$y = 0.0418x - 0.0183 ; R2 = 0.9911$$

3.4.5. Determination of ascorbic acid content

Determination of ascorbic acid content was performed by following method described in Kumar *et a*l. (2013) using 2,6-dichloroindophenol titration method. Flour (2 g) was extracted with 50 mL of (3% MPA and 8% acetic acid) for MPA-acetic acid extraction which was prepared from (15g of metaphosphoric acid (HPO_3) mixed with 40 mL of HOAC (acetic acid) in 500 mL of deionized H_2O). The extract was filtered using Whatman filter paper No.1 and directly titrated by using idophenol solution prepared by dissolving 50 mg of 2,6 dichloro indophenols sodium salt and 42 mg of $NaHCO_3$ to 200 mL with deionized water to a light but distinctive rose pink endpoint lasting ≥ 5 sec. Vitamin C standard was prepared by diluting about 50 mg of L. ascorbic acid into 50 mL of HPO_3-HOAC extracting solution.

Mg of ascorbic acid equivalent to 1.0 mL of indophenols solution=

$$\frac{\text{mg of ascorbic acid in 2 mL of standard solution}}{\text{Titer of indophenol solution}}$$

$$\text{Vitamin C content (mg/g)} = \frac{(A-B) \times C \times 50}{10S}$$

Where: A =Volume in mL of the indophenol solution used for the sample

B = Volume in mLof the indophenol solution used for blank

C = mass in mg of ascorbic acid equivalent to 1.0 mL of standard indophenol solution

S = Weight of sample taken (g)

50/10: 50 = volume of extract for extraction of methaphospheric and acetic acid used &

10 volume of extract used for the titration.

3.5. Determination of antioxidant capacity

The antioxidant capacity of taro corm flour extract was performed based on two different assays.

3.5.1. DPPH (2, 2-Diphenyl-1-picrylhydrazyl) radical scavenging capacity

DPPH radical scavenging assay was performed according to the method described by Yadav *et al*. (2017). This method depends on the reduction of purple DPPH radicals to a yellow colored diphenyl-picrylhydrazine and the remaining DPPH radicals that show maximum absorption at 517 nm was measured (Scherer *et al*., 2009). Briefly, 0.1mM DPPH solution was made in methanol and 1mL of this solution was mixed with 1mL of the extract concentrations in methanol. The mixture was thoroughly vortex mixed and left in the dark at room temperature for 30min. After 30 min of incubation in the dark, at room temperature, the absorbance of the mixture was read at 517 nm using UV spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL Nº 124-244). Ascorbic acid was used as standard for calibration curve which is in the annex part. The ability of dried extract and standard to scavenge DPPH radical was finally calculated based on the formula given below:

$$\text{DPPH radical \% Inhibition} = \frac{(Ac - As)}{Ac} X\ 100$$

AC = Absorbance of control; AS = Absorbance of sample

3.5.2. Determination of ferric reducing antioxidant power (FRAP) assay

The FRAP of each sample extract was determined according to the method described by Benzie and Strain (1996). The assay was based on the reducing power of antioxidant compound present in the sample extract having a potential of reducing the ferric ion (Fe^{3+}) to the ferrous ion (Fe^{2+}); latter forms a blue complex (Fe^{2+}/TPTZ), which increases the absorption at 593 nm. Briefly, the FRAP reagent was prepared by mixing acetate buffer (300 mM, pH 3.6), a solution of 10 mM TPTZ in 40 mM HCl, and 20 mM $FeCl_3$ at a ratio of 10:1:1 (*v*/*v*/*v*). Then, sample extract (100 µL) and 225 µL of deionized water were added to the FRAP reagent (3.400 µL) and mixed thoroughly on a vortex mixer. The tube with its content was kept in the dark at room temperature and absorbance was read at 593 nm after 30 min with UV-Vis spectrophotometer (CECIL INSTRUMENTS CAMBRIDGE ENGLAND SEREAL Nº 124-244). Fresh working $FeSO_4.7H_2O$ solution in methanol was used as a standard and FRAP values were expressed as µmol Fe^{2+}/g on a dry matter basis

(µmol Fe $^{2+}$/g dm) standard curve shown in annex prepared and FRAP value was calculated from the curve ($y = 0.0015x + 0.5445$, $R^2 = 0.9366$).

3.6. Determination of functional properties

3.6.1. Bulk density (BD)

The BD of the taro flour was determined according to the method described by Gupta *et al.* (2015). A weighed amount of taro flour sample (*ca* 2. 0 g) was carefully added into a calibrated 10 mL graduated cylinder. The test tube was tapped several times on the laboratory bench to compact the taro flour until there was no further decrease in volume. Bulk density was calculated as the weight of taro flour (g) per unit volume of sample (g mL^{-1}) as shown below:

$$\text{BD}\left(\frac{\text{g}}{\text{ml}}\right) = \frac{\text{Weight of flour}}{\text{Final volume of flour}}$$

3.6.2. Water absorption capacity (WAC)

WAC was determined using the method modified and followed by Falade *et al*. (2015). Flour sample (*ca* 1.0 g) was added to 10 mL of distilled water in a 25 mL graduated conical centrifuge tubes. The content was stirred and the suspensions were allowed to stand and hydrate at room temperature for 1 hrs. The suspension was centrifuged (Sigma 2-16KC, USA) at 3500 rpm for 30 min. The supernatant was carefully decanted and then the hydrate of flour sample was reweighed and recorded. WAC was expressed as percent water absorption per gram of dry flour based on the original sample weight.

$$\text{WAC} = \frac{\text{Weight retained}}{\text{Weight of sample}} \text{X } 100\%$$

3.6.3. Determination of oil absorption capacity (OAC)

The method modified and described in Falade *et al*. (2015) was used for the determination of OAC of the flour samples. Refined soybean oil with density of 0.92 g/mL was used for this purpose. Flour blend (*ca* 1 g) was added into a 50 mL centrifuge tube and to which 10 mL of oil was added. Then, the content in the centrifuge tube was stirred for 5 min using a magnetic stirrer in a 50 mL centrifuge tube and then centrifuged at 3,500 rmp for 30 min in centrifuge

(Sigma 2-16KC). Thereafter, the amount of oil separated as supernatant was measured using measuring cylinder of capacity of 10 mL. The difference in volume was taken as the oil absorbed by the sample and expressed in percentage.

$$\text{OAC} = \text{Initial volume of oil} - \text{Volume of oil separated as Supernatant}$$

The results were expressed as percentage of oil absorbed by the flour sample.

3.6.4. Water solubility index (WSI)

WSI was calculted by using the decanted supernatant in SP determination step as desctribed in a previous study (Falade *et al*., 2015). The supernatant obtained from SP determination step was poured into a pre-weighed evaporating dish and dried at 100 °C for 20 min to a constant weight. The weight of the evaporating dish and the solublezed particulate of the flour sample were recorded together. The difference in weight of this mass and evaporating dish was used to calculate flour water solubility index, and the WSI was expressed as the percent by weight of dissolved flour from a heated solution as depicted below.

$$\text{WSI}\left(\frac{\text{g}}{100\text{g}}\right) = \frac{\text{Weight of dissolved solid in supernatant}}{\text{weight of flour}} \text{X } 100$$

3.6.5. Swelling power (SP)

SP was determined following method modified by Falade *et al*. (2015). Flour sample (0.35 g) was weighed and added into distilled water (12.5 mL) in a 25mL graduated cylinder. The tube was heated in a water bath at 60 °C for 30 min, with constant gentle stirring to remove trapped air bubbles. Then, the tube was cooled to room temperature in an ice-bath and centrifuged 3500rpm for 20min. The supernatant was decanted carefully from the hydrate together with some cloudy solids which should be poured with clear supernatant. The weight of the sediment hydrate sample in the centrifuge tube were recorded and considered as the $W_{s.}$ SP was expressed as weight of the paste or hydrate per the weight of original flour per gram dry flour as shown in the formula below:

$$SP = \frac{\text{Ws paste}}{(\text{weight of sample})} \left(\frac{g}{g}\right)$$

3.6.6. Determination of dispersibility (DP)

Dispesibility determination was performed following the modified method of Oluwole *et al*. (2016). Flour sample (10 g) was dispersed in distilled water in a 100 mL measuring cylinder and distilled water was added up to 50 mL mark. The mixture was stirred vigorously and allowed to settle for 3hrs. The volume of settled particles was then recorded and percentage of flour dispersibility was calculated following the formula given below:

$$\text{Dispersibility} = \frac{(50 - \text{Volume of settled particle})}{50} X100\%$$

3.7. Bread making and quality evaluation

For the sensory evaluation part, bread was prepared by straight dough bread making procedure with taro wheat composite flour. According to Emmanuel *et al*. (2010), incorporation of taro flour up to 10% with wheat flour bread will not significantly change the sensory properties of the composite bread. Based on this recommendation, mixture design was used for determination of the proportions of taro corm flour included in bread making. Accordingly, maximum taro inclusion of 30% and minimum of zero was used in the design. Then, the design has generated proportion all formulations used for this experiment. The proportions were indicated below:

Table 3.6: Formulation ratios of wheat taro composite bread generated by mixture design

Component 1 A: Wheat flour (%)	Component2 B: Taro flour (%)
92.5	7.5
77.5	22.5
70	30
70	30
85	15
100	0
100	0

Bread was baked using the above listed five ratios. Ingredients water, salt, sugar, fat and yeast were mixed at 140mL, 20g, 140g, 20g and 10g yeast respectively (Ayele *et al*., 2017). All these ingredients were mixed in pan for approximately 5 min. The dough was then kneaded manually for 10 min at 43°C, allowed to rise for 40 min followed by 2 min of punching and leveling of the dough. The procedure was repeated 2 more times as for usual bread making process and the dough was put into baking pans (250 g) and baked for 35 min at 235°C (Emmanuel *et al*., 2010).

Figure 3.8: Wheat taro composite bread

After bread was prepared from these composite ratios, then the bread was kept for an hour till its temperature falls to the level that it can be served before being provided for the panelists for sensory evaluation.

3.7.1. Physical quality evaluation

Loaf Volume, Loaf weight and Specific loaf volume

Bread loaf volume was measured by rapeseed displacement method as described in a previous study (Mudgil *et al*., 2016). Rapeseeds were poured into the container of known volume until the bottom was covered. The loaf was placed inside the container which was then filled to the top with more seeds. The extra rapeseeds, which is equal the to the loaf volume, were measured in a graduated cylinder. The loaf volume was determined from the difference between the initial volume of the rapeseeds and the final volume after placing of the loaf in it. Loaf weight was simply measured by placing the loaf on an electronic weighing balance (Soehnle Professional 9230) as it is described in Mudgil *et al*. (2016). The specific volume

was determined by using the ratio of the two parameters above, loaf volume to loaf weight as proposed in Mudgil *et al*. (2016) based the equation below:

$$\text{Specific volume (cm3 /g)} = \frac{\text{Loaf volume}}{\text{Loaf weight}}$$

3.7.2. Proximate composition analysis of bread samples

Proximate analysis of bread samples were performed using standard procedures similar to that of taro flour as described and followed by Ayele *et al*. (2017).

3.7.3. Sensory evaluation of bread

Sensory evaluation was conducted according to the method of Darkwa *et al*. (2013). For this purpose, a consumer panel of 50 members (25 male and 25 female), aged 22-30 years from the staff and graduating students of the Food Science and Postharvest Technology department of JUCAVM were involved to conduct an affective acceptance test. The consumers were instructed to evaluate the degree of liking to taste, texture, flavor, crust color, crumb grain appearance and overall acceptability of fresh bread. The bread was cut into slices (10 mm thick) and served in disposable uniform service plate coded with three random digits to avoid bias along with an individual evaluation form. Water was served in plastic cups to allow the assessors to clean their palate between each sample. The panelists evaluated the sensory properties of the breads in individual booths illuminated with white light using a 7-point hedonic scale ranging between "like very much" (7) and "disliked very much" (1) with the detail description of scale indicated below.

Table 3.7: The seven point hedonic scale with their respective description used for sensory evaluation

Hedonic scale(7- pts)	English expression
1	disliked very much
2	disliked moderately
3	disliked
4	Neither like nor dislike
5	Like
6	Like moderately
7	Like very much

3.8. Statistical analysis

All chemical analyses were performed in triplicate and the experimental design used for the statistical analysis was Completely Randomized Design (CRD) with 6 varieties. The first two are released taro varieties, and the other four are accessions which are on the pipe line to be promoted to the status of variety. Data generated were subjected to ANOVA analysis to determine the effect of variety by GLM Procedure of SAS (SAS, 2014). For each response, the validity of model assumptions was verified by examining the residuals as described in Montgomery (2017). Where the effect of variety was found to be significant, multiple means comparison was completed, and letter groupings generated using Tukey's multiple range tests at 5% level of significance. Mixture design 6.0.2 was used for formulation of ingredients intended to be used in bread making by using flour from Kihaque variety.

4. RESULTS AND DISCUSSION

4.1. Proximate composition of corms of taro varieties

The proximate compositions of taro flours of different varieties/accessions are shown in Table 8. The findings showed that variety had a significant ($p < 0.05$) effect on the proximate compositions.

The moisture content of flour samples ranged from 5.25 (Ac-21 variety) to 7.84 g/100 g (Danu variety) on dry weight basis (dwb). Fresh taro corms are of high moisture contents and thus, susceptible to deterioration. This hampers the storage stability of the corms, leading to postharvest loss. The lower moisture content obtained for taro flours in this study may suggest better storage potential of the flour and better contribution towards food and nutrition security in rural parts of Ethiopia where taro is commonly grown.

The protein content of taro flour of different varieties/accessions varied between 4.03 (Kihaque) and 9.28 g/100 g (Ac-18) on the dry weight basis (dwb) ($p < 0.05$). The protein contents of taro corm flour were comparable to that in other taro varieties ranging from 5.83 to 9.14% in a previous study (Adane *et al.*, 2013). Protein content of taro flour from different varieties comparable to that in yam (4.36%) and areal yam (6.18%) reported in literatures (Celestine *et al.*, 2015). Some accessions such as accession Ac-18 and Ac-21 contained higher protein contents than other root crops such as anchote 3.25% indicated in literature (Habtamu *et al.*, 2014). However, the protein content of taro flours obtained in this present study are still low as compared to the protein content of legume flour which could be as high as 21.50 to 43.13% (Alghamdi *et al.*, 2018, Millar *et al.*, 2019). Thus, protein sourced from taro corm flour may not sufficient choice similar to other roots and tubers. This indicates that taro flour may need to be blended with other protein rich plant foods such as legumes to produce high protein food.

Lower fat contents of taro flour obtained between 0.160 g/100 g (Ac-18 variety) and 1.23 g/100 g (Ac-21) in this study, were comparable with that of other taro varieties (Boloso I and Acc.236000) (0.47% to 0.65%) from Ethiopia (Adane *et al.*, 2009). As compared to other root

crops, the fat contents were comparable with that reported for anchote (0.19%) (Habtamu *et al*., 2014) and lower than the reported for underground yam (3.51 %) and areal yam (3.30%) (Celestine *et al*., 2015). The variation in fat content could be attributed to the crop botanical origin.

Table 4.8: Proximate composition (g/100 g) and energy value (Kcal/100 g) of taro varieties/accessions

Varieties/Accessions		Proximate composition						
		Moisture	Protein	Fat	Fiber	Ash	Carbohydrate	Energy
Varieties	Kihaque	7.54^{a}	4.03^{e}	0.500^{c}	5.06^{a}	7.14^{a}	83.3^{b}	354^{e}
	Danu	7.84^{a}	5.38^{d}	0.330^{d}	3.49^{bc}	5.41^{c}	85.4^{a}	366^{bc}
Accessions	Ac-5	5.49^{b}	6.32^{c}	0.840^{b}	4.90^{a}	6.11^{b}	81.8^{bc}	360^{d}
	Ac-12	6.00^{b}	7.74^{b}	1.13^{a}	3.61^{bc}	5.68^{bc}	81.9^{bc}	368^{ab}
	Ac-18	5.93^{b}	9.28^{a}	0.160^{e}	4.08^{ab}	5.37^{c}	81.1^{c}	363^{cd}
	Ac-21	5.25^{b}	8.23^{b}	1.23^{a}	2.96^{c}	5.63^{bc}	81.9bc	372^{a}
CV		9.29	6.26	12.1	14.0	5.75	1.10	0.720
LSD		1.07	0.780	0.150	1.09	0.620	1.66	4.76

The crude fiber contents of taro varieties ranged from 2.96 g/100 g (Ac-21) to 5.06 g/100 g (Kihaque) ($p < 0.05$). Comparable crude fiber content range (0.3-3.8%) was reported for other taro varieties (Mbofung *et al*., 2006) while wider variation in fiber content of taro (5.02-13.57 %) was reported in other studies (Trinidad *et al*., 2010, Azene *et al*., 2017). Compared to other root crops, the crude fiber obtained was close to the reported for anchote (2.58%, Habtamu *et al*., 2014) and sweet potato (4.0%, Meludu 2010), but slightly higher than the obtained for root and areal yams 8.70 and 7.79% , respectively (Celestine *et al*., 2015).

The total ash content, which could be the measure of the total amount of minerals were ranging between 5.37 g/100 g (Ac-18) and 7.14 g/100 g (Kihaque) in taro flour ($p < 0.05$). Kihaque variety, followed by accession Ac-5 registered high ash contents. This higher ash content may be indicating that these samples could probably contain substantial amounts of dietary minerals as confirmed in earlier report (Adane *et al*., 2009). The total ash content was

close to the values (4.46-5.44%) reported for other taro varieties from Ethiopia (Adane *et al*., 2009), and the reported (0.90 to 7.78%) for other varieties from elsewhere (Huang *et al.*, 2007; Nijoku *et al*., 2007). On the other hand, total ash contents were found slightly higher than the literature values reported 2.43% for root yam and 2.33% areal yam (Celestine *et al*., 2015). The high ash content of taro in general is an indication that taro may be considerable source of different dietary mineral.

The carbohydrates were the predominant proximate constituents (81.1 g/100 g to 85.4 g/100 g) in taro varieties studied in this research (Table 8). Danu variety had the highest carbohydrate content (85.4 g/100 g), being significantly different from the rest of the samples. The values of carbohydrate contents in this study is in line with those reported in literatures (77.09 to 85.65%) indicating taro as high carbohydrate containing crop (Adane *et al*., 2009, Kumar *et al*., 2015). This is slightly higher than the carbohydrate content (76.68 and 77.49) reported for areal and root yam respectively (Celestine *et al*., 2015).The total carbohydrate contents were statistically non significant ($p > 0.05$) for other varieties (Table 8). Based on the results of this study, Danu variety could be explored for use in formulation of food with enhanced level of carbohydrate. The gross energy contents of taro varieties, which ranged between 354 Kcal/100g and 372 Kcal/100g on dwb was comparable with the range (372.55kcal/100g and 375.11Kcal/100g) reported for other taro varieties (Adane *et al*., 2009). Higher energy contents of taro varieties may probably indicate that these varieties could be good choices to exploit in formulation of energy dense foods meant for human diet.

4.2. Mineral compositions

The mineral contents of taro varieties are presented in Table 9. Significant ($p < 0.05$) difference was observed in the mineral contents of taro varieties. Results showed that mineral elements such as K (1375 to 2525), P (111 to 397), Mg (269 to 209) and Ca (31.7 to 120) in mg/100g of dry flour were found in high amounts. Kihaque variety was found to be a good source of K and P while Ac-21 and Ac-5 were found to contain high levels of Mg and Ca, respectively. The mineral elements such as Zn (17.0 - 62.0), Na (20.0 – 30.0), Fe (7.31 to 20.7) and Mn (0.650 to 13.2) in taro varieties of the present study were found in lower concentration as compared to the levels of K, P, Mg and Ca.

The Ca, P and Na contents of taro obtained in this study could possibly indicate that consumption of taro alone may not help to meet the recommended daily allowance of individuals. The RDA value of Na (500 to 2400 in mg) (Yenenesh *et al*., 2016), P (700 mg (Huang *et al*., 2007) and for Ca (1000 to 1200 mg) highlights taro varieties need supplementation from other sources rich in these mineral elements. K, Fe, Zn, Mn and Mg contents of taro on the other hand could possibly meet their respective RDA (316.72 and 334.71, 8.0 to 18mg, 8.0 and 10 mg, 1.8 and 2.3mg and 320 to 420 mg) respectively indicated in literatures provided that taro is consumed in sufficient amount (Huang *et al*., 2007).

Table 4.9: Mineral composition and contents (mg/100g) of flour of taro varieties/accessions

Varieties/accessions		Minerals mg/100g							
		K	P	Mg	Ca	Zn	Na	Fe	Mn
Varieties	Kihaque	2525^{a}	397^{a}	212^{bc}	33.4^{d}	54.4^{b}	30.0^{a}	8.06^{de}	1.93^{cd}
	Danu	1450^{e}	117^{e}	208^{c}	31.7^{d}	36.4^{b}	20.0^{c}	19.4^{b}	13.2^{a}
Accessions	Ac-5	1875^{b}	258^{c}	235^{b}	120^{a}	17.3^{e}	25.0^{b}	8.83^{d}	0.650^{d}
	Ac-12	1550^{d}	204^{d}	223^{bc}	83.0^{b}	17.0^{e}	25.0^{b}	20.7^{a}	2.65^{c}
	Ac-18	1375^{f}	263^{b}	217^{bc}	60.2^{c}	62.0^{a}	25.0^{b}	7.31^{e}	1.17^{cd}
	Ac-21	1700^{c}	111^{f}	267^{a}	83.0^{b}	26.7^{d}	25.0^{b}	10.6^{c}	4.72^{b}
LSD		684.15	4.63	24.12	4.79	3.34	2.74	0.99	0.79
CV		1.52	1.13	5.83	3.84	5.15	4.26	4.35	10.78

The contents of Na, K and P of taro varieties in this study revealed that they are comparable to that of areal and underground yams, 38.52 to 39.80, 316.72 to 334.71 and 149.93 and 156.09 mg/100g , respectively (Celestine *et al*., 2015). Iron and magnesium content obtained for taro varieties were higher than the value (5.49 mg/100 g and 79.73 mg/100 g respectively) reported for raw anchote flour (Habtamu *et al*., 2014). Likewise, zinc content of taro corm flour found in this study was also higher than that of anchote and underground yam 2.23 and 0.36, respectively (Habtmu *et al*., 2014; Celestine *et al*., 2015). Mn content of taro corm flour was higher than that of underground yam 0.46mg/100g (Celestine *et al*., 2015). Lower Ca content was obtained for taro varieties in this present study than the value (119.50 mg/100 g) and (280.25mg/100g) reported for anchote and underground yam by Habtamu *et al*. (2014) and Celestine *et al*. (2015), respectively.

4.3. Anti-nutritional factors composition of taro corm flour

The oxalate, phytate and condensed tannin antinutritional factors are shown in Table 10 except alkaloid antinutrient which is not indicated because it was not significantly affected by varieties/accessions. Variety/accession had significant ($p < 0.05$) effect on the contents of antinutritional factors analyzed except for total alkaloid content ($p > 0.05$) with overall mean value of 8.20 %.

Table 4.10: Anti-nutritional compositions of taro varieties

Treatment		Anti-nutrients		
		Oxalate(mg/100g FW)	Phytate (mg/100g	Condensed tannin (mg/100g)
Varieties	Kihaque	56.7^{a}	6.28^{f}	57.4^{d}
	Danu	24.3^{d}	28.9^{a}	60.8^{cd}
Accessions	Ac-5	35.8^{c}	24.1^{c}	95.2^{b}
	Ac-12	35.1^{c}	17.2^{d}	118^{a}
	Ac-18	40.5^{b}	26.2^{b}	134^{a}
	Ac-21	44.6^{b}	9.0^{c}	80.6^{bc}
LSD		4.33	1.75	19.91
CV		7.27	5.16	12.01

The total oxalate contents of taro corms varied between 24.3mg/100 g for Danu variety and 56.7mg/100g for Kihaque variety on the dwb of the flour ($p < 0.05$). The values are comparable with the reported (65mg/100g; 70 mg/100g to 130mg/100g) in literature previously (Savage *et al*., 2007; McEwan *et al*., 2008). However, the oxalate contents of taro varieties in this study were lower than the range (243 to 265.9mg/100 g) reported for other taro varieties (Adane *et al*., 2009), but higher than the values (3.52mg/100 g; 20 mg/100 g to 60 mg/100 g) reported by other authors (Agwunobi *et al*., 2002; Wills *et al*., 1983). Such variation may be attributed to different factors related to environment and genetic variability. The oxalate content reported in this study for taro varieties are therefore in a safe margin because toxic and lethal level of oxalates has been reported to be between 3-5 g for man as indicated in literature (Ekop *et al*., 2008). Traditional processing methods have been suggested to reduce oxalate content of taro corms (Adane *et al*., 2013).

The phytate content ranged from 6.28mg/100 g for (Kihaque) to 28.9 mg/100 g for (Danu) ($p < 0.05$). The phytate content was higher than the value (1.75mg/100 g) reported by Abdulrashid *et al*. (2009). On the other hand, the phytate contents found were lower than the values (31.17mg/100 g to161.13 mg/100 g; 117.4 mg/100g to 135.3 mg/100g) reported in different literatures (Akalu *et al*., 2017; Adane *et al*., 2009). Such difference in phytate content among literatures may be attributed to taro varieties and environmental condition in which they grow. The phytate reported for flour of taro varieties in this study is therefore below the maximum acceptable dose in the body which ranges between 250 and 500mg/100g (Ekop *et al*., 2008).

Tannin contents of taro varieties/accessions ranged from 57.4 in Kihaque to 134 mg/100g in Ac-18 (Table 10). The observed range was comparable with range (47.69 to 59.91mg/100 g) reported in a previous study (Adane *et al*., 2009) except Ac-18 and Ac-12 accessions. On the other hand, tannin contents were lower than the value (280 mg/100 g) reported in a previous study (Olajide *et al*., 2011), but higher than the obtained (0.14mg/100g) in literature (Agwunobi *et al*., 2002). These variations may be due to the variation in growing condition of different geographical regions. The tannin contents reported for the flour of taro varieties in the present study were found to be low to cause adverse effect on the health of the consumers as it was lower than the acceptable daily intake (560 mg) reported in literatures (Habtamu *et al*., 2014).

Kihaque variety containing lower condensed tannin and phytate contents appears preferable. These anti-nutrients are known to bind with divalent and trivalent mineral elements, protein and starch to form insoluble complexes, jeopardizing the utilization of these nutrients (Adane *et al*., 2013; Habtamu *et al*., 2014). Danu variety could be recommended due to its lower oxalate content, a major limiting factor for a wider utilization of taro corms in human diet.

4.4. Anti-nutrients and minerals molar ratios

4.4.1. Phytate (Phy): minerals and oxalate (Ox): calcium molar ratios

The molar ratios of phy to mineral (calcium, iron, and zinc) and oxalate to calcium (Ox: Ca) obtained from the taro are shown in Table 11. Variety had a significant ($p < 0.05$) effect on

the molar ratios of phyate to minerals and oxalate to calcium. The Phy:Ca, Phy:Fe, Phy:Zn, [Phy] [Ca]: [Zn] and the Ox:Ca molar ratio for the taro flour varieties ranged from 0.007 to 0.056, 0.066 to 0.304, 0.011 to 0.137, 0.010 to 0.410 and 0.139 to 0.773 respectively. Phytate to mineral molar ratio values are indexes of mineral bioavailability than mineral contents alone (Habtamu *et al*., 2014). A molar ratio of Phy:Ca lower than 0.24, Phy : Fe: lower than 1 and Phy : Zn less than 15 is acceptable for adequate calcium, iron and zinc absorption, respectively (Umeta *et al*., 2005).

Taro varieties/accessions used in this study recorded less Phy: Ca molar ratio than the critical molar ratio values suggested. This indicates that the phytate content did not considerably affect the bioavailability of calcium of the varieties/accessions. Similarly, molar ratios of Phy:Fe and Phy:Zn obtained were also below the indicated critical value, implying that the phytate content of taro flour did not significantly affect the bio-availability Fe and Zn.

The highest Phy:Fe molar ratio was reported for Ac-18 which indicates that Fe is less bio-available in this variety relative the other accession (Table 11). The lowest molar ratio of Phy:Fe (0.661) was reported for Kihaque variety indicating higher Fe bioavailability for this variety relative to the other varieties/accessions. Similarly, highest Phy:Zn molar ratio (0.137) was reported for Ac-5 which indicates lower bioavailability of zinc for this variety compared to the other varieties. The lowest molar ratio (0.011), hence, highest bioavailability was reported for Kihaque taro variety with respect to Phy:Zn. Thus, Kihaque is preferable variety in terms of phytate: (Fe, Zn and Ca) molar ratios than different varieties though all varieties scored molar ratio below the critical value.

The [Phytate][Ca]:Zn molar ratio calculated in this study were found between 0.010 in Kihaque variety and 0.410 in Ac-5 variety as shown in Table 11. This ratio is important because, zinc bioavailability is known to be affected by calcium mineral when phytate content of the food is high; and thus, [Phytate] [Ca]: Zn molar ratio is suggested to be a better index of zinc bioavailability in plant food apart from Phytate:Zn molar ratio alone (Habtamu *et al*., 2014) due to synergism between calcium and zinc ions that will result into less soluble Ca:Zn:Phy complex. As suggested by Habtamu *et al*. (2014), [phytate] [Ca]: [Zn] ratio greater than 0.5 mol/Kg (0.05 in mol/100g) is the critical value for this molar ratio. This study

therefore highlighted that [Phytate][Ca]:Zn molar ratio is by far lower than critical value reported in literature above. However, Kihaque variety is relatively the best variety in terms of zinc bioavailability with respect to [Phytate][Ca]:Zn.

Table 4.11: Molar ratios of phytate to calcium, iron, and zinc, oxalate and phytate *calcium to zinc of flours of different taro varieties/accessions

Varieties/accessions		Molar ratios of anti-nutritional factors to mineral				
		Phy: Ca	Phy: Fe	Phy: Zn	Phy*Ca:Zn	Ox: Ca
Varieties	Kihaque	0.011^{c}	0.066^{d}	0.011^{e}	0.010^{d}	0.773^{a}
	Danu	0.056^{a}	0.126^{c}	0.078^{c}	0.063^{c}	0.340^{b}
Accessions	Ac-5	0.012^{c}	0.234^{b}	0.137^{a}	0.410^{a}	0.139^{e}
	Ac-12	0.013^{c}	0.071^{d}	0.101^{b}	0.209^{b}	0.192^{de}
	Ac-18	0.026b	0.304^{a}	0.042^{d}	0.063^{c}	0.306^{bc}
	Ac-21	0.007^{c}	0.075^{d}	0.034^{d}	0.071^{c}	0.242^{cd}
Critical values		0.24	1	15	0.5	2.5

The oxalate to calcium molar ratio between 0.139 and 0.773 in Ac-5 and Kihaque respectively were reported. These reports are below the critical value (2.5) indicated in literature (Habtamu *et al*., 2014) and therefore, taro corm flour is a reasonable source of total calcium with only a small proportion bound to oxalates. Danu variety is relatively a better source of bioavailable calcium than Kihaque variety.

4.4.2. Phytate phosphorus and none phytate phosphorus

The phosphorus as phytate reported in this study ranges between 0.004 and 0.069. The lowest (0.004) was reported for Kihaque variety indicating the best bioavailability than the others while the highest (0.069) was for Danu variety. But, Phosphorus as Phytate in all varieties/accessions is below the indicated critical level (50%, 0.05 as indicated in Yenenesh *et al*., 2016) which is an indication for bioavailability of phosphorus. This phosphorus as Phytate is as good index for level of biologically available phosphorus in food samples due to the fact that phytate form complex and hence, reduce the bioavailability of phosphorus minerals in food stuffs when taken in higher amount (Yenenesh *et al*., 2016).

Table 4.12: Phytate phosphorus and non-phytate phosphorus contents of six taro varieties/accessions

Varieties/accessions		Phytate p	Non phytate p	Phosphorus as phytate
Varieties	Kihaque	1.77^{f}	395.25^{a}	0.004^{e}
	Danu	8.14^{a}	109.19^{d}	0.069^{a}
Accessions	Ac-5	6.80^{c}	250.94^{b}	0.026^{bc}
	Ac-12	4.86^{d}	198.77^{c}	0.024^{cd}
	Ac-18	7.37^{b}	255.13^{b}	0.028^{b}
	Ac-21	2.60^{e}	108.24^{d}	0.023^{d}
LSD		0.494	4.82	0.003
CV		5.16	1.21	5.47

4.5. Phytochemical compositions

4.5.1. Phenolic contents

The total phenolic content of taro varieties varied from 39.5 GAE (mg/ g) (Ac-5) to 57.8 GAE (mg/ g) (Ac-18) ($p < 0.05$). Comparable total phenolic content (TPC) of 14 and 21 mg GAE/ g was reported for white and red taro varieties, respectively (Ferreres *et al*., 2012). Kumar *et al*. (2017) reported the total phenolic content of taro flour extract in the range of 6.32 to 15.14 mg GAE/ g, while Ribo *et al.* (2018) reported 0.75 mg GAE per /g in the tuber extract of taro. The TPC of taro corm varieties used for this study were slightly higher than those reported for cassava (8.35 and 10.88 mg GAE/ g) (Omar *et al*., 2012). The variation in TPC in different literature may be attributed by different factors including varietal, environmental factors and methods of analysis as well.

Table 4.13: Phenolic, flavonoid, β-carotene and ascorbic acid composition of dried taro corm flour

Samples		Antioxidant compounds			
		TPC Galic acid equivalent (mg GAE/g)	TFC mg of catchein equivalent/g	β-carotene (mg/100g)	Ascorbic acid (mg/100g)
Varieties	Kihaque	50.39^{ab}	6.20^{a}	11.3^{cd}	11.0^{b}
	Danu	45.13^{bc}	4.67^{c}	10.4^{d}	13.0^{a}
Accessions	Ac-5	39.45^{c}	5.57^{abc}	13.2^{b}	13.0^{a}
	Ac-12	40.32^{c}	5.80^{ab}	13.5^{b}	12.3^{ab}
	Ac-18	57.83^{a}	6.27^{a}	18.5^{a}	12.0^{ab}
	Ac-21	46.01^{bc}	5.27^{bc}	12.6^{bc}	12.0^{ab}
LSD		9.84	9.24	1.80	0.02
CV		11.62	9.02	7.47	8.88

The total flavonoid contents (TFCs) of taro varieties ranged from 4.67 (Danu variety) to 6.27 (Ac-18) mg of catchein equivalent (CE)/g of flour. According to the finding of this research, Ac-18 had the highest flavonoids of 6.27 mg of catchein equivalent/g, followed by 6.20 in Kihaque, 5.80 in Ac-12, 5.57 in Ac-5, 5.27 in Ac-21 and 4.67 in mg of catchein equivalent /g for Danu variety (Table 13). According to Simsek *et al*. (2015), the average total flavonoid content in taro corm extract is about 0.61mg CE/g sample. The difference in results of flavonoid contents in literature may be due to varietal, environmental and methods of analysis as well.

4.5.2. Beta-carotene content of taro corm flour

Beta carotene content in flours of taro varieties ranged between 10.4 to 18.5 mg/100g. The lowest β-carotene (10.4 mg/100g) was for Danu variety while the highest (18.5 mg/100g) was for Ac-18 followed. There was significant ($p < 0.05$) difference between varieties with respect to β-carotene contents. The beta carotene content of taro flours in this study were comparable with those reported (19 mg/100 g) in a previous study (Isabelle *et al*., 2010). The β-carotene contents of taro corm were lower than the range (74.4 to 93.61 g/100 g) reported for other taro varieties on dry matter basis (Huang *et al*., 2007). It is also apparent that the β-carotene contents of taro varieties fall within the range (2.107 to 93.6mg/100 g) reported in different

literature (Huang *et al*., 2007, Nguimbou *et al*., 2013). These variations with respect to β-carotene contents of taro corm flour may attribute to different varieties grown different climatic conditions.

4.5.3. Ascorbic acids content of taro corm flour

The ascorbic acid contents of taro varieties were found to range from 11.0 to 13.0 mg/ 100g ($p < 0.05$). Danu varieties and Ac-5 recorded the highest ascorbic acid content 13.0 mg/100g while the lowest scored was 11.0 mg/100g for Kihaque varieties (Table 13). Higher values of ascorbic acid content (31.54 and 29.16 mg/ 100 g (dry weight)) than the report in this study was reported for fresh raw corms and cormels of the cocoyam in literature (James *et al*., 2013). While ascorbic acid content for taro corm flour reported by these authors (8.95mg/100g) was lower but comparable to the result of this finding. The values of this study are also higher than the range of 7 – 9 mg/ 100 reported by Onwueme (1978). Similarly, ascorbic acid content of 2.95 to 15mg/100g was also reported in literature (Huang *et al*., 2000, Isabelle *et al*., 2010, Maga *et al*., 1992).

4.6. Antioxidant capacity of taro corm flour extract

4.6.1. DPPH (2, 2-Diphenyl-1-picrylhydrazyl) radical scavenging capacity

Percent DPPH inhibition/Scavenging: DPPH radical inhibition of taro flour extract was minimum (25.5% for Kihaque, 30.7% for Danu, 34.7% for Ac-5, 34.0% for Ac-12, 32.7% for Ac-18 and 27.9% for Ac-21) at lower concentration (200 µL/ mL) and highest (67.9% for Kihaque, 62.0% for Danu, 72.5% for Ac-5, 70.9% for Ac-12, 83.7% for Ac-18, and 63.4% for Ac-21) at higher (560 µL/ mL) concentration. The Ac-18 showed the highest DPPH inhibition at 330, 430, 500 and 560 µL/ mL concentrations. This observation was in line with the result reported in previous studies (19.35 ± 0.82% by Yadav *et al*., 2017) whereby DPPH radical scavenging capacity of phenolic extract of taro flour was shown to be concentration dependent and increases with parallel increase in the concentration (Kasote *et al.*, 2011).

Table 4.14: Antioxidant capacity of extracts of taro varieties/accessions

Varieties/accessions		Concentration (µg / mL)			
		200	330	500	560
Varieties	Kihaque	25.5^{c}	41.6^{b}	64.2^{ab}	67.9^{bcd}
	Danu	30.7^{abc}	41.2^{b}	57.9^{ab}	62.0^{d}
Accessions	Ac-5	34.7^{a}	46.9^{ab}	63.2^{ab}	72.5^{b}
	Ac-12	34.0^{ab}	47.8^{ab}	65.3^{ab}	70.9^{bc}
	Ac-18	32.7^{ab}	49.6^{a}	71.4^{a}	83.7^{a}
	Ac-21	27.9^{bc}	40.8^{b}	54.2^{b}	63.4^{cd}
LSD		6.37	7.95	15.01	8.47
CV		8.03	6.93	9.37	4.71

The graphs of concentration versus average % scavenging capacity are shown in Annex for the six varieties. From the graphs, one can see and understand that antioxidant activities are concentration dependant.

The IC50 value: The IC50 values of taro corm extract in this study ranges from the lowest (338 µg/mL in Ac-18) to the highest (436 µg/mL in Ac-21). The DPPH value could also be expressed in terms of what is called IC_{50} and the lower values of IC50 are indicating powerful antioxidant while the higher the values of IC50 are indicating less potent the antioxidant activity. The concentration of corm extract in our case were between 200 and 560 µg/mL and the high IC50 values reported in this study attributed to this high concentrations of extract similar to other reports (*Yadav et al.*, 2017) ; Akshatha *et al.*, 2018) for which concentration ranged from 50 to 200 µg/mL and 25 to 400µg/mL respectively. The IC50 value of this study are comparable with the reported (74.34 ± 12.17µg/mL) in Yadav *et al.* (2017) and 23.3 µg/mL and 21.4µg/mL in Akshatha *et al* (2018) for corms grown in green house and micro propagated plant respectively.

All the extracts of taro corm varieties/ accessions exhibited antioxidant activity though there are differences in extent of this property between varieties ($p < 0.05$). The extract of Ac-18 demonstrate lowest with IC50 value of 338 µg/mL, hence, best antioxidant capacity followed by Ac-5 (351µg/mL), Ac-12 (353 µg/mL), Kihaque (404 µg/mL) Danu (421µg/mL) and finally Ac-21 (436 µg/mL). There is no statistically significant difference between Kihaque, Danu and Ac-21 taro varieties. But, there is significant difference in the scored IC50 value of

Ac-18 and Ac-21 taro varieties. The IC50 value for Ac-21 is the highest which indicates it is lower in its antioxidant capacity relative to the rests of varieties.

Table 4.15: IC50 values and FRAP of taro extract

Varieties/accessions		IC50 value	FRAP (mM Ferric sulfate equivalent)
Varieties	Kihaque	404^{abc}	128^{c}
	Danu	421^{ab}	122^{c}
Accessions	Ac-5	351^{bc}	145^{bc}
	Ac-12	353^{bc}	157^{b}
	Ac-18	338^{c}	188^{a}
	Ac-21	436^{a}	167^{ab}
LSD		81.14	25.81
CV		8.22	9.37

4.6.2. Ferric reducing power (FRAP)

FRAP values of taro corm extract in this study ranged between 122% and 188% (Table 15). The variety did not affect ($p > 0.05$) the FRAP values of Kihaque and Danu varieties. These varieties scored statistically lower FRAP values, which could be indication for lower concentration of antioxidant compounds than the other varieties. Ac-18 is exhibited significantly highest FRAP value of 188%. In line with this finding, Eugenio *et al*. (2017) reported 167.99% mM Ferrous sulfate for taro corm extract. Higher FRAP values ranged from 343% to 679% was reported by Jeon *et al*. (2016) (mM Ferrous sulfate /100g) though the authors are using other thermal processing than drying alone. The variation antioxidant capacity in different literatures may be related to varietal difference, environmental factors, methods used for determination and processing methods.

4.6.3. Pearson correlation coefficients of antioxidant capacity and compounds

Correlation analysis was performed to investigate the association between pairs of various phytochemicals and antioxidant capacity in taro varieties. Pearson's linear correlation coefficients were calculated and results are presented in Table 16. FRAP and DPPH values (at the two highest concentration of 500 µg/mL and 560 µg/mL) were positively and strongly correlated with total phenolic contents ($r = 0.43$ and 0.53 and 0.52 respectively). The positive

correlation of total phenolic contents with the two antioxidant assay could be possibly explained by the antioxidant capacity of the compound. Similar correlation results were previously reported whereby total phenolic contents have strong positive correlation with the antioxidant capacity (Sirawdink *et al*., 2013). The IC50 value and total phenolic compounds were weakly and negatively correlated as indicated in Table 16.

Table 4.16: Pearson Correlation Coefficients

Parameters	TPC	TFC	IC50	FRAP	bet	Asc	D560
TPC.	1.00						
TFC	0.50	1.00					
IC50	-0.07	-0.61	1.00				
FRAP	0.43	0.45	-0.47	1.00			
Beta.	0.57	0.62	-0.73	0.89	1.00		
Asco.	-0.55	-0.68	-0.16	-0.11	-0.09	1.00	
D560	0.52	0.75	-0.88	0.69	0.93	-0.11	1.00

Note: Asco: Ascorbic acid; Beta: Beta carotene; D560 are DPPH inhibition %age at concentrations (560 µg/Ml) of taro corm extract

FRAP and DPPH at 560 concentrations were both strongly correlated with flavonoid content (r= 0.45 for FRAP, and 0.75 for D560 respectively). The correlation between IC50 value and total flavonoid compounds were strongly and negatively correlated (Table 16). The correlation of IC50 value with antioxidant compounds is negative because of the fact that the lower the IC50 value the higher antioxidant capacity and hence high antioxidant compound concentration.

The correlation between β-carotene content and DPPH at 560 µg/mL extract concentration is very strong, positive and statistically significant (p> 0.01, R2 = 0.93 at 560) extract concentration. Similarly, β-carotene content was also strongly and positively correlated with FRAP value (p =0.01 R2 = 0.89) where the correlation was observed to be statistically highly significant.

4.7. Functional properties of corm flours of taro varieties/accessions

The functional properties flours of different taro varieties are shown in Table 17.

Bulk density: Results of bulk density of flours of taro varieties (overall mean = 5.33 g/mL) showed no statistically significant ($p > 0.05$) difference.

Water absorption capacity: WAC of taro corm flours from different varieties ranged from 228% (Danu variety) to 331% (Ac-18). Results of WACs of taro corm flour were comparable with WAC range of 240% to 470% reported in previous studies (Aboubakar *et al*., 2008, Hossain 2016.WAC of flour is used for enabling processor to add more water during preparation, improve handling characteristics and helps to maintain the freshness of baked products like bread and cakes (Kumar *et al*., 2015). This property can be linked to the nature of the starch in the taro flour. Low WAC value indicates compactness of the starch structure while a high value could be attributed to the loose structure of starch polymers. Higher WAC of flour obtained for Ac-18 variety may have the potential to bind water which is a desirable attribute. A higher WAC may be useful in products where hydration is required to enhance handling characteristics such as dough and pastes (Yadav *et al*., 2012).

Oil absorption capacity: The OAC which varied between 173% (Ac-21) and 242% (Ac-5) among taro samples studied (Table 17), were higher than the WAC values (110 to 130% and 137mg/100 g), and respectively reported in an earlier report (Adane *et al*., 2009; Kumar *et al*., 2015). However, the OAC of taro flour samples reported in this study were lower than that of composite flour of wheat flour at 50% inclusion level by taro flour reported in a previous study (Abinet *et al*., 2014). OAC is the capacity of flour protein to physically bind oil by capillary attraction. Thus, it is of great importance as oils act as flavor retainer and increases the mouth feel of the foods, and subsequently improve palatability, and extend the shelf life of bakery products and other food products. On the basis of the findings of this study, taro flour may improve flavor and mouth feel of baked products such as bread when used as partial substitute of wheat flour.

Table 4.17: Functional properties of different varieties of taro corm flour

Varieties/accessions		Properties				
		WAC (%)	OAC (g/100g)	WSI (g/100g)	Swelling power (g/g)	Despersibility (%)
Varieties	Kihaque	300[a]	189[ab]	24.4[a]	6.01[a]	18.7[b]
	Danu	228[b]	183[b]	19.2[b]	4.05[b]	24.0[ab]
Accessions	Ac-5	308[a]	242[a]	22.1[ab]	5.47[a]	19.3[b]
	Ac-12	310[a]	176[b]	20.7[ab]	5.36[a]	22.7[ab]
	Ac-18	331[a]	216[ab]	19.3[b]	5.34[a]	26.0[a]
	Ac-21	235[b]	173[b]	21.1[ab]	5.74[a]	26.7[a]
LSD		63.7	53.7	4.17	0.68	5.93
CV		12.3	15.2	11.0	7.14	14.4

Water solubility index: Water solubility index of taro corm flour in ranged from 19.2% (Danu variety) to 24.4% (Kihaque variety). These values are within the WSI range (11.83% and 25.64 g/100 g) reported in previous studies (Amon *et al*. 2011, Kaushal *et al*., 2012, Kumar *et al*., 2015). It has been reported that WSI of wheat flour was found to increase when the proportion of taro flour get increased in the composite flour intended for development of baked products such as bread (Kumar *et al*., 2015).

Swelling power: The swelling power ranged between 4.05% (Danu variety) and 6.01% (Kihaque variety). Comparable ranges of swelling powers of taro flour (3.18 % to 9.74 %) with the obtained in this study were reported in previous studies (Adane *et al*., 2009, Falade *et al*., 2015). On the other hand, higher SP results (10.99 and 16.02%) than that measured in this study were also reported in literature (Tattiyakul *et al*., 2006). These variations may be due to processing used and varietal difference as well. The swelling power of flours is related to their protein and starch contents (Kaushal *et al*., 2012). As elaborated in this journal, higher protein containing flours may cause the starch granules to be embedded within a stiff protein matrix which limits the access of the starch to water and restricts the swelling. Food eating quality is often connected with retention of water in the swollen starch granules and hence the higher the swelling power the better will be eating quality of food (Falade *et al*., 2015)

Dispersibility: Dispersibility of taro flours ranged from 18.7% (Kihaque variety) to 26.0% (Ac-21 variety). Dispersibility is an index of the ease of reconstitution of the flour samples in

water. Ac-18 and Ac-21 are higher in their dispersibility which indicates flours of these samples have the ability to disperse more easily and faster in aqueous solution during food processing than other samples. The dispersibility is functional property that shows the ease of breakup of agglomerates which allow particles to descend below the surface and scatter quickly in a liquid (Tizazu *et al*., 2010). Thus, the higher dispersibilty in water of flour reported for taro flour samples in this study (26.0% for Ac-21 as example) is an indication that the agglomerates in such flour can easily break up and allow particles to sink below the surface and disperse rapidly in a liquid form making more homogeneous dough.

4.8. Bread quality parameters

4.8.1. Physical quality parameters

Table 18 shows loaf weight, loaf volume and specific loaf volume of bread made from wheat-taro flour blends. The loaf weight appears to increase with increased level of taro flour in the composite flour. The maximum loaf weight was obtained at 15% level of taro flour substitution suggesting that there are irregularities in trends of increase in loaf weight of composite bread with increased level of taro flour inclusion. Such in consistency is result might be attributed to lack of uniformity of internal temperature of baking machine. The bread loaf volume was decreased from 514cm^3(7.5 % level of substitution) to 494 cm^3 at inclusion level of 30% taro flour. Similarly, Sharma *et al*. (2016) reported that an increase in the inclusion level of taro flour resulted in decreased loaf volume of wheat-based composite bread. This may be due to absence of the gluten proteins (gliadin and glutenin) in taro flour, which are known to form an elastic network capable of holding gas and in turn result in higher loaf volume of bread (Abera *et al*., 2017). This suggested that a decrease in the proportion of gluten bearing component (wheat flour) in the composite flour could be probably resulted in smaller loaf volume of wheat-taro composite bread with increased taro flour substitution level.

Table 4.18: Physical properties of wheat taro composite bread

Proportions	Properties		
W-T (%)	Loaf weight (g)	Loaf volume (mL)	Specific loaf volume (cm3 /g)
92.5-7.5	284^{ab}	514^{ab}	1.82^{b}
77.5-22.5	268^{bc}	456^{bc}	1.70^{b}
70-30	290^{a}	494^{ab}	1.70^{b}
70-30	289^{ab}	494^{ab}	1.71^{b}
85-15	291^{a}	501^{ab}	1.72^{b}
100-0	264^{b}	549^{a}	2.09^{a}
100-0	211^{c}	427^{c}	2.03^{a}
LSD	25.9	60.90	0.18
CV	4.06	5.25	4.23

Bread of the highest specific volume (2.03 and 2.09 cm^3 /g) was baked from 100% wheat flour (control bread). No significant difference ($p > 0.05$) in the specific volume of bread samples baked from wheat-taro composite flour with different inclusion level of taro flour. This is in line with the reported in a previous study in which the specific volume of wheat-taro composite bread decreased with an increase in the levels of taro flour in the blend (Sharma *et al*., 2016).

4.8.2. The proximate composition of wheat-taro composite bread

The proximate composition of wheat-taro composite flour breads is shown in Table 19. The moisture content of fresh composite bread samples were non-significant ($p > 0.05$) among the formulations which is 43.91 g/100 g on average. The mean protein scored for the bread samples of different formulation is 8.14 g/100 g and substitution of wheat flour by taro flour did not cause statistically significant change on this protein content.

Significantly higher fat content (4.25 g/100 g) was obtained for bread at 7.5% inclusion level by taro flour while the lowest fat content of 1.91 g/100 g was recorded for control bread (100% wheat flour) ($p < 0.05$). However, the variation in fat content of composite bread samples is not consistent to draw conclusion about the effect of an increase in the inclusion level of taro flour in the blend the there could be increasing trend in general. These non

consistencies may have resulted from lack of uniformity that could exists in internal baking machine structure.

Table 4.19: Proximate composition (g/100 g) and energy value (Kcal/100 g) of taro wheat composite bread

Proportions (%) W-T	Proximate compositions				
	Moisture	Fat	Fiber	Ash	Energy value
92.5-7.5	3.32^{bc}	4.25^{a}	2.05^{b}	1.86^{bc}	406^{a}
77.5-22.5	3.17^{d}	3.55^{b}	3.37^{a}	2.00^{b}	396^{b}
70-30	3.14^{d}	3.63^{b}	1.88^{b}	3.15^{a}	398^{b}
70-30	3.45^{a}	3.53^{b}	1.89^{b}	3.10^{a}	398^{b}
85-15	3.20^{d}	2.30^{c}	2.41^{ab}	2.96^{a}	390^{c}
100-0	3.27^{bcd}	1.91^{c}	2.12^{b}	1.78^{c}	394^{bc}
100-0	3.36^{ab}	1.92^{c}	1.67^{b}	1.80^{c}	396^{bc}
LSD	0.13	0.57	0.97	0.19	5.33
CV	1.60	7.74	18.06	4.57	0.55

W= Wheat T = Taro

The fiber contents of composite breads ranged between 1.67 g/100 g (100% wheat flour) and 3.37 g/100 g (22.5%) taro flour inclusion level. It is apparent that the fiber content of bread samples tends to increase with an increase in the inclusion level of taro flour in the blend. This could be attributed to high fiber content of taro flour (Table 8). A good number of previous studies have confirmed the same observation whereby an increased level in taro flour in the blend has been accompanied by increase in the crude fiber content of wheat-taro flour (Ammar *et al.*, 2009; Alflen *et al*., 2016). The ash content of the bread samples reported in this study ranged between 1.78 g/100 g (control breads (100% wheat bread) and 3.15 g/100 g (30% taro flour substituted composite bread). This observation was in agreement with the reported by previous scholars who reported that the ash content wheat-taro composite bread increases with an inclusion level of taro flour in the blend (Alflen *et al*., 2016; Sanful, 2011).

There is no significant ($p > 0.05$) difference in the carbohydrate content of bread samples of which the overall mean was 82.87 g/100 g (Table 19).The energy content of composite bread samples ranged between 390 Kcal/100 g (15% taro inclusion) to 406 Kcal/100g (7.5% taro substituted bread). The energy content of bread samples recorded was comparable with the

reported for wheat-taro composite bread (421.63kcal/100 g to 406.53kcal/100 g) in a previous study (Lamrot, 2018).

4.8.3. Sensory properties of taro flour substituted wheat bread

The mean sensory scores for quality attributes of bread samples evaluated are presented in Table 20. Significant differences ($p < 0.05$) were observed among bread samples of different formulations in the sensory attributes (taste, crumb grain, flavor, appearance, color and overall acceptability). The control (100% wheat flour) bread scored better degree of liking in all sensory attributes evaluated than the taro flour substituted composite bread (Table 20). The finding is in accordance with those of previous studies which indicated higher acceptability of 100% wheat bread than wheat-taro composite flour bread at all levels of substitution in all sensory parameters (Sharma *et al.*, 2016). These authors further underlined that acceptability of bread declines with increase in the inclusion level of taro flour in the blend. The overall acceptance test measures whether consumers like or accept a new product, and thus, it is a good indicator of sensorial acceptance of products suggesting that control bread is the most acceptable.

Table 4.20: Sensory attributes of taro flour substituted wheat bread

Formulation W-T (%)	Sensory parameters						
	Taste	Crumb grain	Flavor	Texture	Appearance	Color	Overall acceptability
92.5-7.5	5.89^{b}	5.94^{b}	5.67^{b}	5.63^{b}	5.69^{bc}	5.78^{b}	5.89^{b}
77.5-22.5	5.38^{c}	5.27^{c}	5.11^{bc}	5.22^{bc}	5.00^{cd}	4.50^{c}	5.29^{c}
70-30	4.85^{d}	4.94^{cd}	4.88^{c}	4.94^{c}	4.69^{d}	4.82^{cd}	4.89^{cd}
70-30	4.73^{d}	4.71^{d}	4.56^{c}	4.82^{c}	4.64^{d}	4.51^{d}	4.63^{d}
85-15	5.95^{b}	5.82^{b}	5.61^{b}	5.57^{b}	5.64^{bc}	5.53^{b}	5.81^{b}
100-0	6.42^{a}	6.29^{a}	6.30^{a}	6.26^{a}	6.38^{ab}	6.33^{a}	6.56^{a}
100-0	6.49^{a}	6.40^{a}	6.41^{a}	6.37^{a}	6.49^{ab}	6.53^{a}	6.65^{a}
LSD	0.35	0.34	0.63	0.42	0.79	0.40	0.45
CV	2.56	2.46	4.66	3.80	5.90	2.97	3.21

Generally, sensory scores of various attributes decrease as proportion of taro flour increases in the blend. The highest sensory score of closer 6 (like moderately) was recorded for most of the sensory attributes by two 100% wheat flour bread. The degree of liking for different sensory attributes were close to 6 (like moderately) for a bread sample baked from a

composite flour which was substituted at 15% level by taro flour and thus up to 15% partial substitution is similar to control in terms of the attributes evaluated. Bread sample baked from composite flour at 22.5% and 30% inclusion level by taro flour score close to 5 (like) in different sensory attributes. Thus, it is possible to conclude that inclusion up to 15% of wheat by taro flour in bread making will not significantly affect the degree of liking of the composite bread. Partial substitution of wheat flour above 22% however may slightly lower the degree of liking in the sensory properties than the control bread and 15% taro flour inclusion levels in the blend. Similar to the findings of this study, previous studies reported that increasing proportions of taro flour in the composite decreased the sensory attributes of wheat-taro composite bread (Abera *et al*., 2017; Eddy *et al.*, 2012; Eduardo *et al*., 2015). High level of oxalate in taro corms has been suggested by scholars as it is among factors to decrease the sensory properties such as taste in wheat-taro composite flour bread (Abera *et al*., 2017).

5. SUMMARY AND CONCLUSION

5.1.Summary

Taro is one of the major underutilized and less studied crops in Ethiopia as its consumption similar to most other roots and tubers is limited to just boiling and consuming the roots. It is among the considerable sources of carbohydrate, fiber, mineral, some vitamins and other non-nutritional components having anti-oxidant properties. The evaluated taro varieties possess comparable proximate composition though Ac-18, Ac-21 and Ac-12 scored maximum protein and energy while a Kihaque variety is highest in fiber and ash. The mineral compositions of taro varieties were comparable though Kihaque scored highest Na, K and P and Ac-12 highest in Fe and Ac-18 in Zn while Ac-21 and Ac-5 were highest in Mg and Ca respectively. With respect to anti-nutrient to mineral molar ratios, the entire molar ratios reported in this research were below the critical value. The mineral bioavailability in Kihaque is better in relative to the other varieties as molar ratios were lower except in oxalate Ca molar ratio. The functional properties of the flour from the corms of taro are also indication that there are high potentials of the crop to be used in development of different food products. Thus, taro could be one option to be considered as partial substitute of wheat flour in bread making.

The production of wheat is low to meet the demand for bread production and our country is importing from other county to meet this demand. Utilization of roots and tubers like taro as partial substitute of wheat could therefore contribute towards tackling of such problems in our country. Thus, partially substituting wheat flour by taro flour as high as 15% was not significantly affects the consumer acceptance of bread. The 22.5 and 30% inclusion of taro could decrease the consumer acceptance but, still with acceptable (5, Like) degree of liking. Therefore, it is possible to partially substitute wheat flour by taro flour in bread making as high as 30% with slightly acceptable sensory parameters and minimum or no effect in some of the proximate and physical quality of the bread.

5.2. Conclusions

The present study has revealed that variety had a significant effect on the nutritional composition (proximate and mineral nutrients), antinutritional factors except alkaloids,

functional properties except for bulk density, phytochemical content and antioxidant capacities of taro varieties. Results of proximate analysis showed that varieties/accessions Ac-18, Kihaque and Ac-5 could be recommended as good sources of protein, total ash and crude fiber contents, respectively. Potassium was the most abundant mineral while manganese was found in trace amount in all the varieties relative to other mineral constituents. Kihaque variety containing lower condensed tannin and phytate contents could be recommended for use in food preparation while Danu variety could be recommended for its lower oxalate content. Results of functional properties of taro flour also exhibited potential utility of taro flour in food formulations such as in bread making. The phytochemicals of all taro varieties demonstrated antioxidant capacities as measured by DPPH and FRAP assays. Though it is not uniform for all varieties, it could be concluded that bread with acceptable sensory quality can be obtained from these varieties at about 15% taro flour substitution level and beyond this level, bread sensory characteristics may be negatively affected. Overall, given taro is one of the underutilized crops in Ethiopia, this study highlights the potential of taro flour for bread making and beyond to promote its utilization for human diet.

5.3. Recommendation for future line of work

In view of the findings of this study and conclusion made, the following recommendations are made for further study:

- Given the presence of uninvestigated varieties and locally available taro landraces across the country, comprehensive characterization of their food and nutritional value must be undertaken.
- Further studies could target evaluation of the performance of flours of these varieties for use in different traditional Ethiopians foods and industrial foods.
- The effect of different processing methods on some limiting factors (anti-nutritional factors) to wider taro utilization and high quality taro flour (HQTF) should be investigated.
- More in-depth study should be conducted on composite flour dough rheological properties.

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ANNEXES

Standard curve of gallic acid (**Figure 1A**), catechin hydrate (**Figure 1B**) and beta-carotene (**Figure 1C**), and standard phytic acid (**Figure 2A**) and catechin hydrate (**Figure 2B**), and standards of antioxidant assays (DPPH, **Figure 3A** and FRAP, **Figure 3B**), and scorecard (**Table 1**) for sensory evaluation of control and composite bread samples.

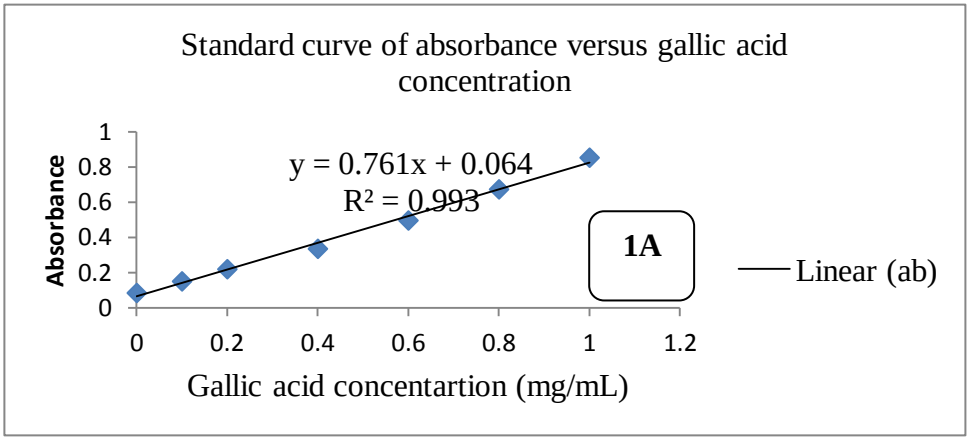


Figure 1A: Standard curve of absorbance versus concentration of gallic acid

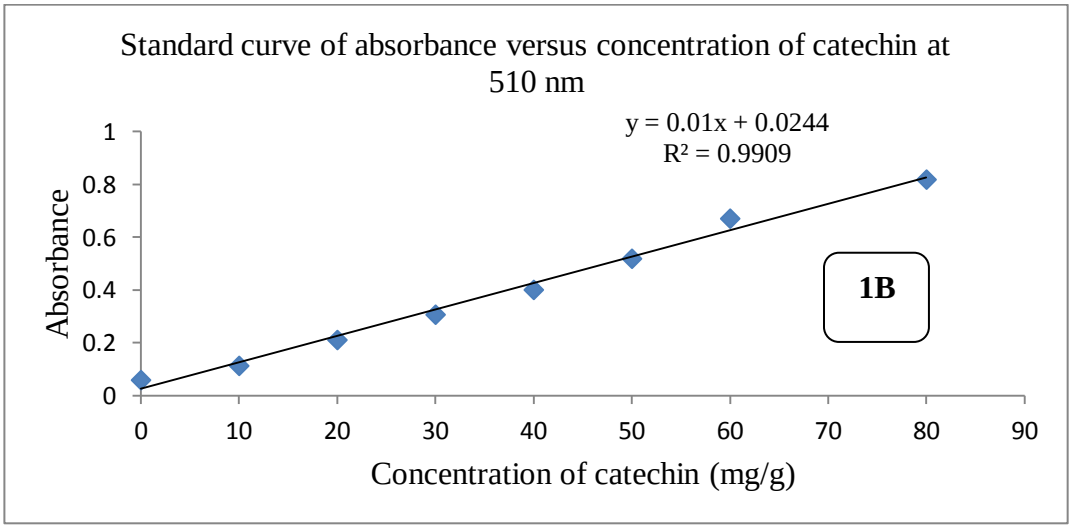


Figure 1B: Standard curve of absorbance versus concentration of catechin

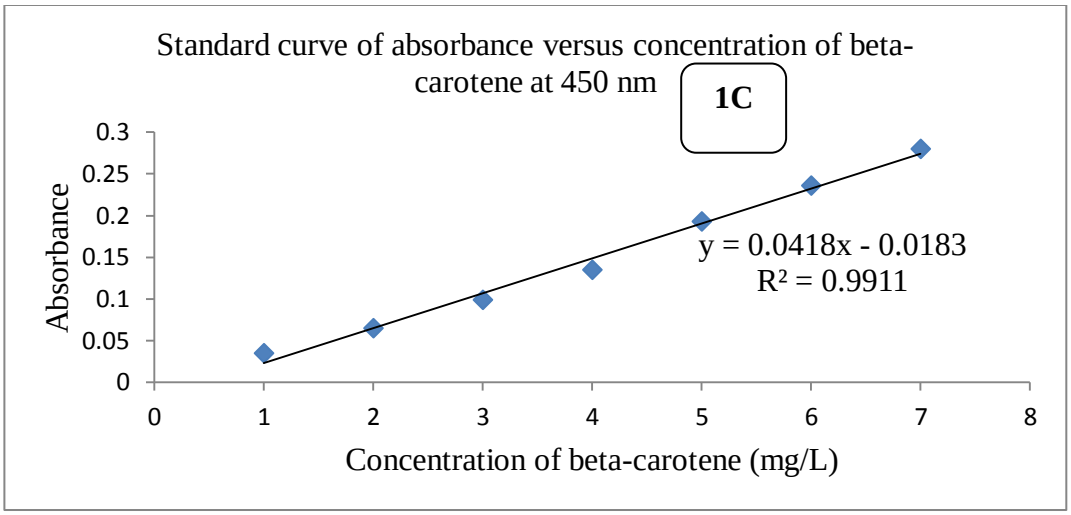


Figure 1C Standard curve of absorbance versus concentration of beta-carotene

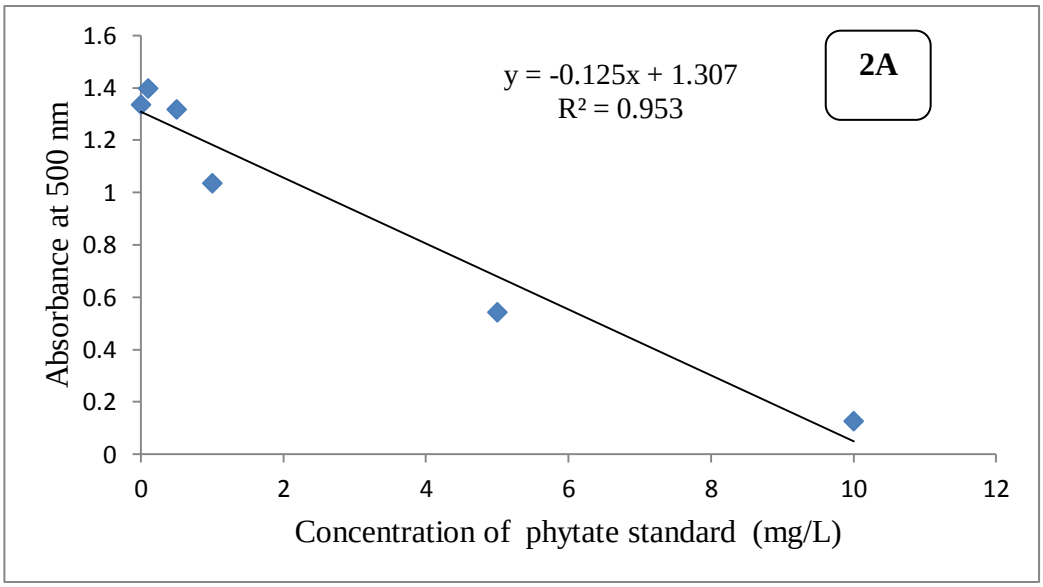


Figure 2A Standard curve of absorbance versus concentration of phytic acid at 500 nm

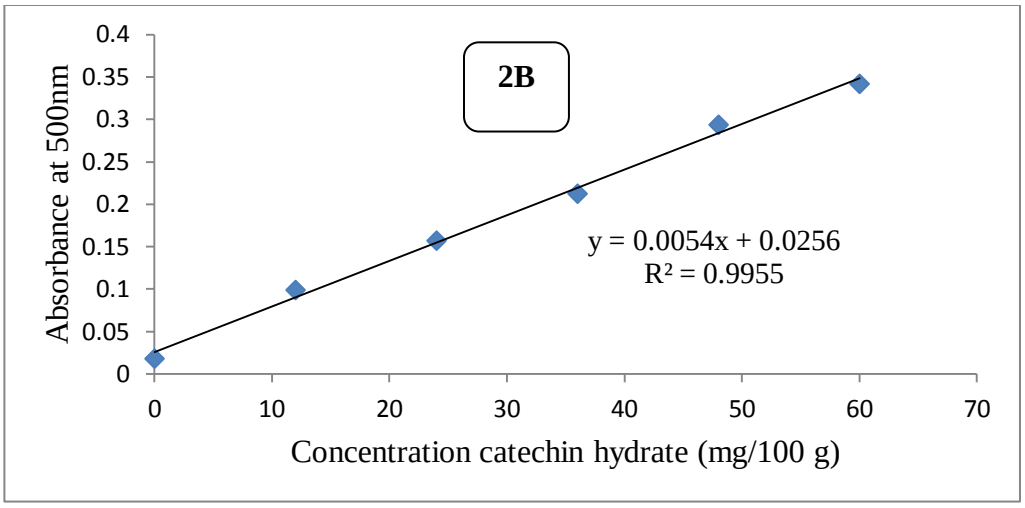
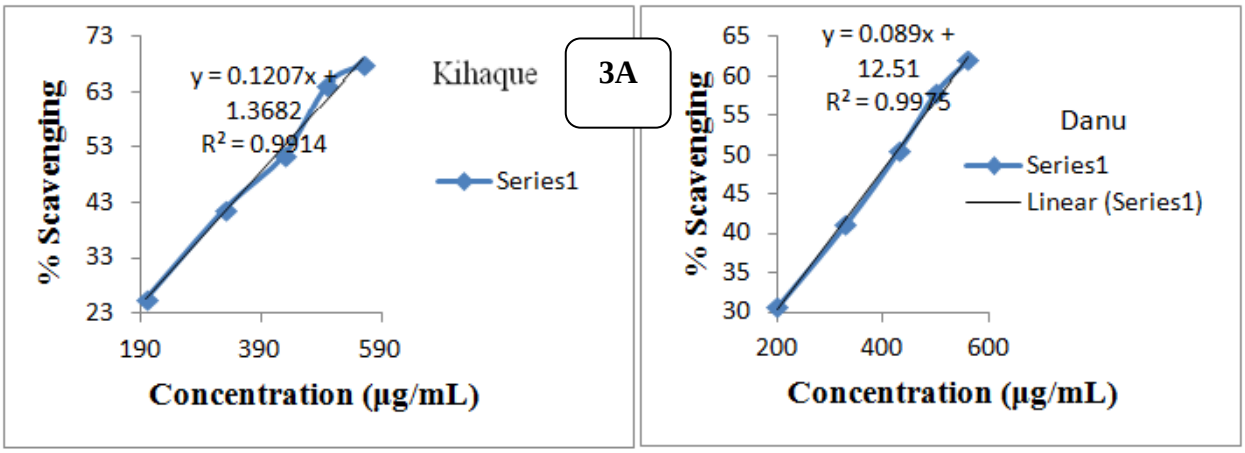
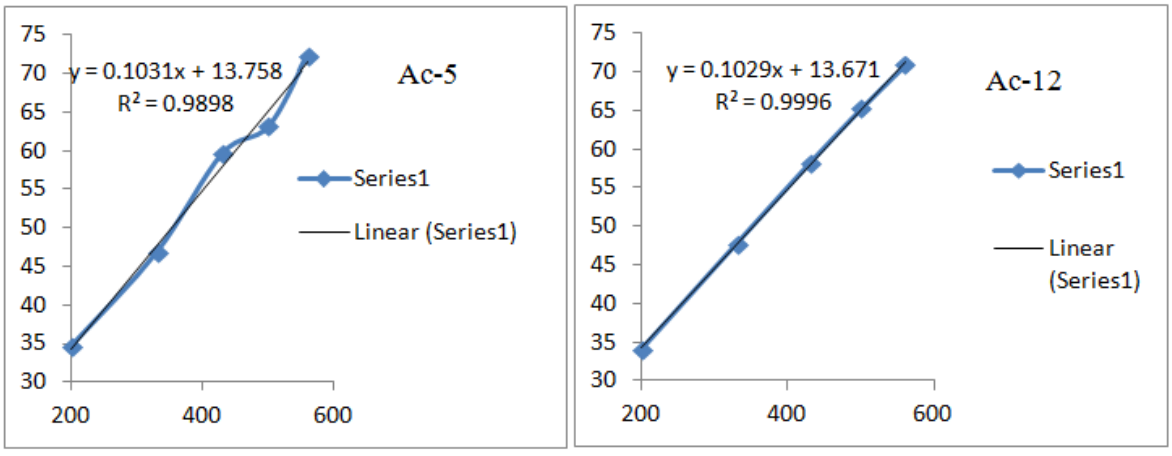


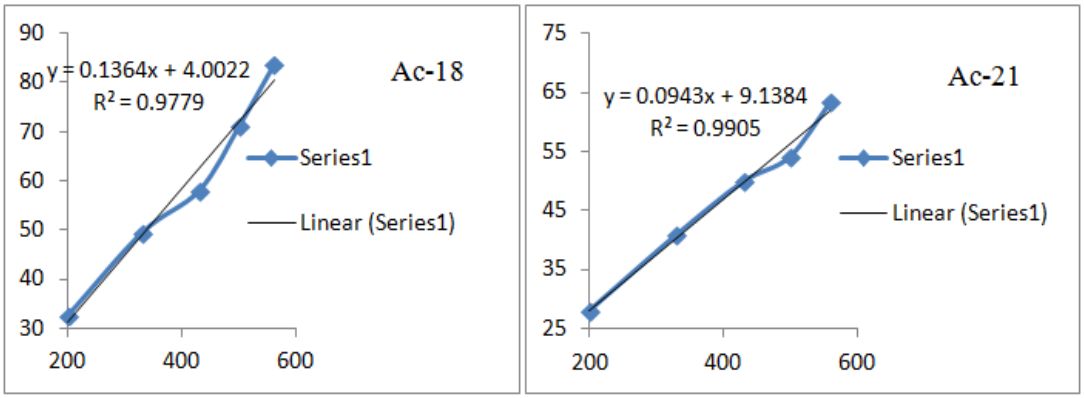
Figure 2B Standard curve of absorbance versus concentration of catechin hydrate



Percent scavenging capacity of Kihaque (Left) and Danu (right handed) variety extract



Percent scavenging capacity of Ac-5 (Left) and Ac-12 (right handed) variety extract



Percent scavenging capacity of Ac-18 (Left) and Ac-21 (right handed) variety extract

Figure 3A Concentration verses absorbance curve for DPPH assays of different varieties of taro

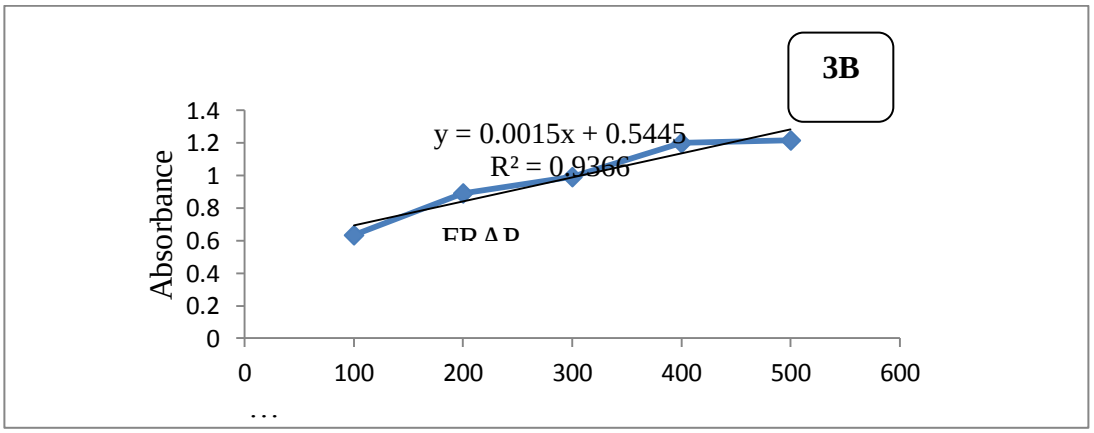


Figure 3B: Standard curve of $FeSO_4.7H_2O$ for FRAP assay

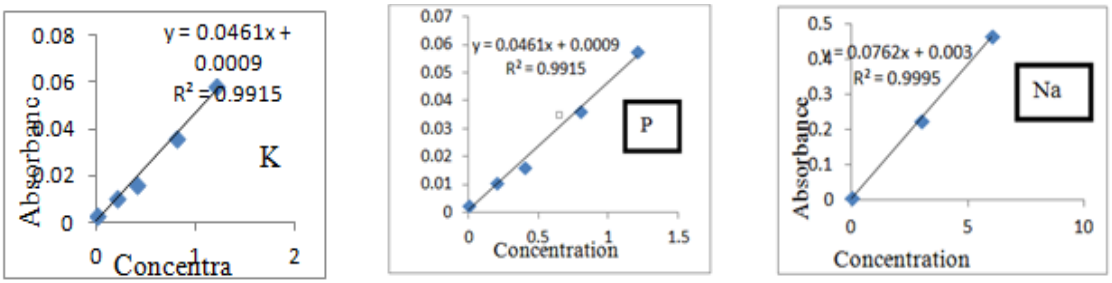


Figure 3C: Standard curve for K, P and Na minerals respectively

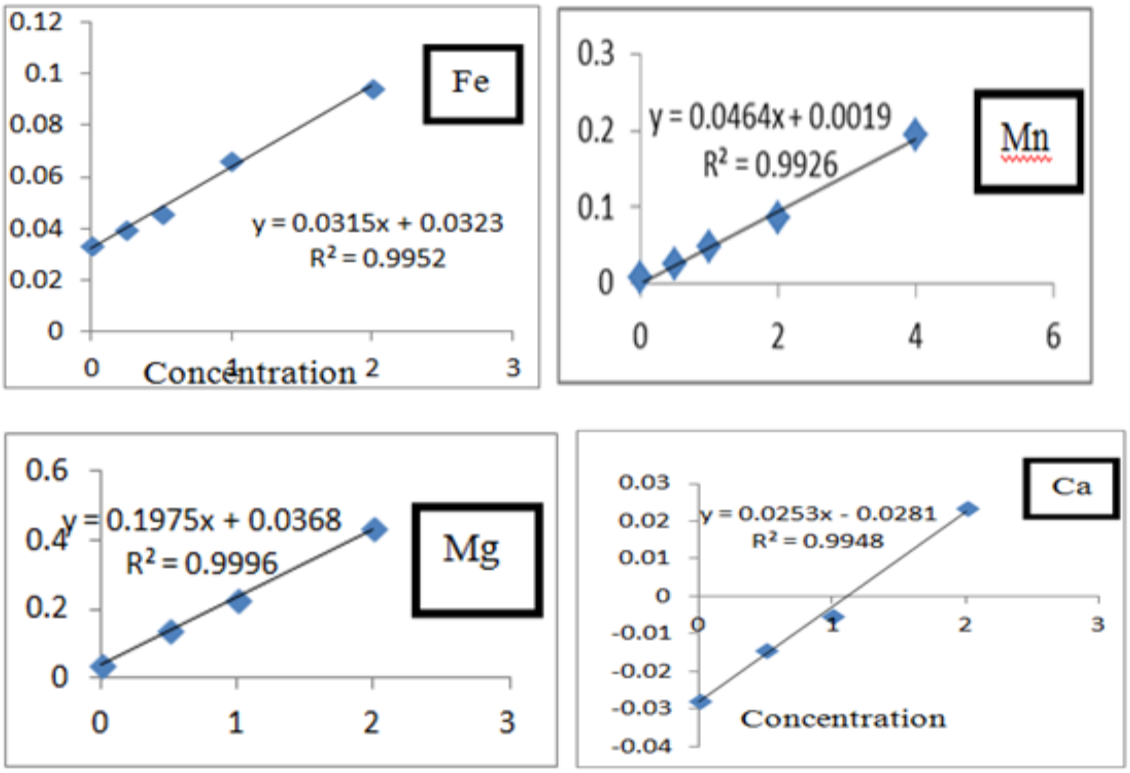


Figure 3C: Standard curve for Fe, Mn, Mg and Ca minerals respectively

Sensory evaluation data collection form

Dear consumer panels, I am working on consumer attitude toward bread baked from partially substituted wheat flour by taro corm flour as a partial fulfillment of my M.Sc study in Food Science and Technology. Thus, your attitude is needed here for successful completion of this study. The information you give will only be used for the research purpose and I assure that it will be kept confidential. Thus, I kindly request your cooperation. You do have the right not to respond to the whole question in case you are not comfortable with the questions; but your response is very valuable for the accomplishment of the work.

Thank you indeed!
Name_____
Sex_____

Table 1 Scorecard for sensory evaluation of bread samples

Sample code	Parameters						
	Taste	Crumb grain	Texture	flavor	Appearance	Color	Overall acceptability
AZ							
BY							
CX							
DW							
EV							
FU							
GT							

Hints: **AZ**- 7.5 % Substitution, **BY**-22.5% Substitution, **CX**-30% Substitution, **DW**- 30% Substitution, **EV**- 15% Substitution, **FU** and **GT**-Control (100% Wheat bread)

Hedonic scale(7- points)	English expression
1	disliked very much
2	disliked moderately
3	disliked
4	Neither like nor dislike
5	Like
6	Like moderately
7	Like very much