

Physical and Proximate Characterization of *Anchote* (*Coccinia abyssinica*) Accessions Grown under Hawassa and Wondo Genet Conditions, Southern Ethiopia

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Abstract
This research was undertaken to investigate the effects of *anchote* accessions and growing areas on the physical and proximate composition of the roots. The physical properties were measured using standard measurements. The major and minor diameters as well as the root peel thickness were measured using a digital caliper. The proximate composition was assessed using standard methods. Both the physical properties (major and minor diameters, aspect ratio, root peel thickness, peel proportion to root and root densities) and proximate compositions of *anchote* roots were significantly influenced by accessions type and growing sites. Over all, better quality, in terms root peel thickness and peel to root ratio, were observed for the accessions grown at Hawassa. The *anchote* accessions grown at Wondo Genet site were observed to have higher levels of crude protein, crude fiber and gross energy than those grown at Hawassa. Higher ash content was associated to the accessions grown at Hawassa site.
Keywords: *Anchote, physical properties, aspect ratio, major diameter, minor diameter, root peel thickness, root density, proximate composition*

1.0 Introduction

Anchote [*Coccinia abyssinica*(Lam.) Cogn.] is a tuber crop cultivated for human consumption in the South-western areas of Ethiopia. *Anchote* belongs to the *cucurbitaceae* family and *conccinia* genus having over 30 *species*, about eight of which are believed to occur in Ethiopia (Mengesha *et al*., 2012; Bekele *et al.,* 2013; Fekadu *et al*., 2013; Yambo and Feyissa, 2013; Yassin *et al.,* 2013). Among the other root crops grown by Ethiopian farmers,*Anchote* is less popular, particularly in the central and south Eastern areas of the country. *Anchote* being among few indigenous vegetable crops in Ethiopia has not studied much and is not well developed and popularized, despite its food and nutrition security and other functional potentials (Gelmessa, 2010; Fekadu *et al*., 2013). While there are many research findings in agronomic and physiological aspects of cereal crops, limited number of researches were conducted and little information has been generated on indigenous root crops such *anchote* and others (Yambo and Feyissa, 2013). According to Gelmessa (2010), there has been no visible effort made to introduce/domesticate new food materials in Ethiopia. The author indicated the presence of over looked, under-developed and under-utilized food items that are not being fully exploited in the fight against hunger. Potential use of those wild foods by the community has been also observed among which *Corchorus olitorius* in Afar Region, *Moringa olifera* in Southern Nation, Nationality and Peoples Region (SNNPR) and *Coccinia abyssinica* in Oromia region (south western part of the country) are contributing significant roles in human nutrition, income generation and medicinal applications (Dawit and Estifanos, 1991; Gelmessa, 2010; Fekadu, 2011; Yambo and Feyissa, 2013).

Anchote is subsistence crop widely grown to fill food security during hunger months. Unlike many other crops, *anchote* can be grown with minimal inputs and it is able to produce reasonably well under unfavorable conditions such as low soil fertility, acidic soils or drought and under intercropping with cereals. *Anchote* has been grown over a wide range of environments (1300-2800 meters above sea level.), with sporadic distribution (Amare, 1976; Abera and Gudeta, 2007). It occurs in many parts of Ethiopia including the western, southern and northern parts (Edward, 1991; Yambo and Feyissa, 2013). It is believed that there are many accessions with potential yields in all growing areas. However, its production and consumption is not as such known in many parts of the county as there were no work done on *anchote* evaluation for agronomic and food quality attributes (Amare, 1973). The current study attempted to introduce *anchote* accessions to Hawassa Zuria and Wondo Genet districts (Woredas) of Sidama Zone, Southern Ethiopia and the roots were evaluated in terms of physical and proximate characteristics. The objective of the trial was to select the accessions that best fit to the two agro-conditions and then distribute them to the different Technology villages of Hawassa University.

2.0 Materials and Methods

2.1. Description of the growing locations

The field study was conducted at two locations, representing two agro ecologies: Hawassa University, Research and Farm Center and Wondo Genet sites under rain fed conditions. Hawassa is the capital of the Southern Nations, Nationalities and Peoples Region (located in southern part of Ethiopia), about 275 Km from Addis Ababa. The site lies at 7° 04' north and 38°3' east and an altitude of 1669 meter above sea level. The area is characterized by the soil type of sandy loam with pH of 7.4 which is volcanic in origin and described as flora soil based on FAO and UNISCO soil classification. The average rainfall of the area is 900-1100 annually while the average annual minimum and maximum temperature are 12.5°C and 27.5 °C respectively (Mekuria*et al.*, 2014; Wondrade*et al.,* 2014).Wondo Genet College of Forestry and natural Resources is located within 7° 13'north and 38° 37' east. The altitude of the area ranges from 1800- 2400 meters above sea level. The mean annual temperature is about 19°C, which is much colder than Hawassa. The area has bimodal rainfall from February to April (short rainy season) and from the end of June to September (long rainy season). The mean annual rain fall is 1200mm (Kassa and Bekele, 2008;Bekele *et al.,* 2013).

2.2. Physical Characterization of Anchote Roots

2.2.1. Shape: Aspect ratio of the roots

Size and shape of the *anchote* roots were estimated using the projection area method where three characteristic dimensions: major and minor diameters, also termed as length and thickness respectively, were measured (Sahin and Sumnu, 2006) using a digital caliper (Model: DC009-150, Zhejiang, China (Mainland)). The aspect ratio was then calculated as a ration of the major to minor diameters (Maduako and Faborode, 1990; Sahin and Sumnu, 2006).

2.2.2. Proportion by weight of peel in theroot

The proportion by weight of peel in the roots of *anchote* was determined by the procedures employed by Ademosun *et al.* (2012) and Oriola and Raji, (2013). Fresh *anchote* roots were weighed using a digital balance (Model: PW 254, Adam Equipment, USA) and recorded as W_r. The roots were carefully peeled manually using sharp stainless steel knives. The peels were collected, weighed and recoded as W_p. The proportion of weight of the peels (PP) of fresh roots to that of total roots was determined by the following formula:

$$PP = \frac{W_p}{W_r}$$

2.2.3. Root density

The density of the different accessions was determined as ratio of mass of the root to its volume (Oriola and Raji, 2013). Representative samples of *anchote* roots were selected and their weights were measured (*M*) using balances. Volumes (*V*) of the roots were estimated non-destructively by liquid displacement technique and the apparent density (ρ) was computed for the different *anchote* accessions as follows:

$$\rho = \frac{M}{V}$$

2.3. Proximate Composition Analysis

Moisture content, total ash, crude protein, crude fiber, and crude fat of the *anchote* tubers were determined using AOAC methods, 925.09, 923.03, 979.09, 962.09, and 920.39, respectively (AOAC, 2000). The total carbohydrate content (including fiber) of the samples were determined by difference method (Atwater and Woods, 1896), which is by subtracting the sum of the percentages of moisture, crude protein, crude fat and ash from 100.

$$Total\ carbohydrate(\%) = 100 - (\%Moisture + \%\ protein + \%Fat + \%Ash)$$

The gross energy content was determined by multiplying percentages of crude fat by Atwater's conversion factors, 9 and that of crude protein as well as carbohydrates by 4 (Tadesse *et al.,* 2015). The sum of the conversions was taken as the gross energy contained by the *anchote* samples.

$$Gross\ energy\ (kcal) = (9 \times \%cf) + [4 \times (\%cp) + (\%tc)]$$

Where $\%\ cf$ = percentage of crude fat, $\%\ cp$ = percentage of crude protein and $\%tc$ = percentage of total carbohydrates

2.4. Experimental Design and Data Analysis

The experiment was arranged in a 10 by 2 factorial design, where 10 accessions over two growing areas were tested for having effect on the physical characterization and proximate composition. The data were analyzed using the analysis of variance (ANOVA) at 95% level of confidence. For the components revealing significant ANOVA, mean separation was carried out using Fischer's least significant difference (LSD).

3.0 Results and Discussion

3.1. Physical Properties of *Anchote*

3.1.1. Effects of accessions on physical properties of *anchote*

The major and minor diameters of the *anchote* accessions varied significantly (Table 1). The highest major and minor diameters (mm) were recorded for the gute and dicho accessions, respectively. Lower major and minor diameters corresponded to the hagallo and alukawusa accessions, respectively. The diameters reported for *anchote* accessions in the current study was a comparable to common edible root crops such as cassava, cocoyam and sweet potato (Ademosun *et al*., 2012; Balami *et al.,* 2012a; Balami, *et al.,* 2012b; Teye and Abano, 2012; Oriola and Rajii, 2013).

The aspect ratio, indication of roundness (shape), was also significantly ($p<0.05$) varied with the different accessions (Table 1). The highest aspect ratio was observed for the alukawusa accession indicating that the major diameter is by far higher than the minor one. The aspect ratio of many of the accessions was close to 1, which indicates that the roots are close to perfect round (Figure 1). The aspect ratio of *anchote* reported in the current study is by far higher than that reported for sweet potato by Balami*et al.,* (2012a). These physical characteristics are important for the design of postharvest handling and processing equipment. They are also used in quality determination as size and shapes of agricultural materials are important quality issues.

Table 3: Effect of Accessions on physical properties of *anchote* roots

Accessions	Diameter (mm)		Aspect Ratio	Peel thickness (mm)	Peel to root ratio (w/w)	Root density (kgm^{-3})
	Major	Minor				
Ago	97.41±8.80^{b}	78.52±9.37^{ab}	1.26±0.20^{bc}	1.75±0.39^{abc}	0.13±0.02^{b}	1113.59±154.59^{a}
Alukawusa	100.91±10.50^{b}	66.97±19.54^{c}	1.60±0.44^{a}	1.88±0.32^{ab}	0.16±0.05^{ab}	993.23±10.61^{c}
Choli Michael	97.52±20.23^{b}	77.68±15.79^{abc}	1.30±0.37^{bc}	1.97±0.12^{ab}	0.15±0.05^{ab}	1025.30±36.81^{bc}
Dicho	85.15±9.83^{b}	84.08±15.22^{a}	1.03±0.12^{c}	1.50±0.15^{c}	0.13±0.02^{b}	1020.14±11.53^{bc}
Gimbi 01	90.38±18.47^{b}	70.95±9.36^{bc}	1.29±0.31^{bc}	1.99±0.25^{a}	0.16±0.04^{ab}	994.61±8.59^{c}
Gute	243.50±372.83^{a}	79.12±10.95^{ab}	1.19±0.17^{bc}	1.99±0.40^{a}	0.15±0.04^{ab}	967.15±101.01^{c}
Hagallo	70.94±34.07^{b}	77.07±11.48^{abc}	1.13±0.16^{bc}	1.67±0.26^{bc}	0.144±0.02^{ab}	1017.93±65.23^{bc}
Jimate	99.37±12.47^{b}	74.96±10.10^{abc}	1.33±0.13^{ab}	2.04±0.29^{a}	0.14±0.01^{b}	1076.03±76.91^{ab}
Jirata	88.83±17.36^{b}	70.88±12.56^{bc}	1.31±0.44^{bc}	2.04±0.08^{a}	0.18±0.05^{a}	988.04±29.80^{c}
Mao	92.15±12.47^{b}	74.22±6.30^{abc}	1.25±0.20^{bc}	1.90±0.29^{ab}	0.15±0.04^{ab}	981.76±49.30^{c}

Figure 4: Illustration of shapes of peeled roots of *anchote*

The peel thickness (mm) of the *anchote* roots accessions were significantly ($p<0.05$) different (Table 1). The accessions: gimbi 01, gute, jimate and jirata were observed to have higher peel thicknesses. Dicho on the other hand was the accessions with the least ($p<0.05$) peel thickness. Unlike many root crops, *anchote* has peels that easily separate like tree barks (Figure 2). This makes it easy for postharvest cleaning. Moreover, the root does not undergo browning on peeling and this is another desirable characteristic for postharvest handling of the fresh roots.

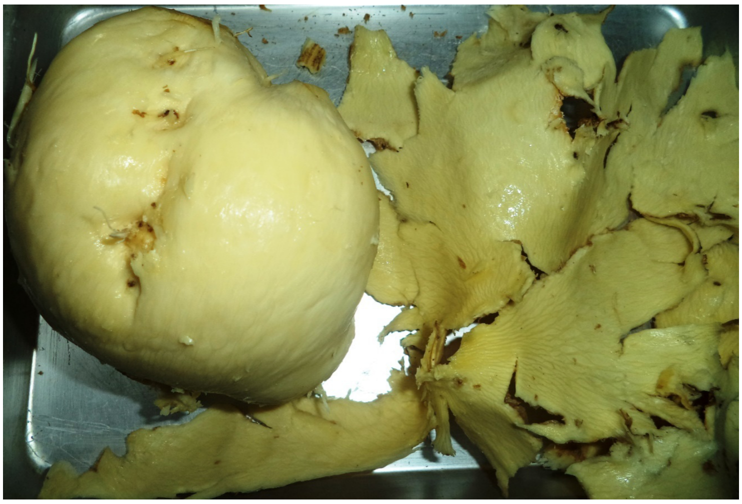

Figure 5: The starchy root and skin (peel) of *anchote*

The peel to root ratio (w/w) was also significantly different for the various accessions of *anchote* (Table 1). Dicho and jimate were the two accessions which had lower peel to root ration, which can be associated with higher proportion of edible part. The root density was also observed to significantly ($p<0.05$) vary for the different accessions (Table 1). Ago and jimate accessions had the higher root density while alukawusa, gimbi 01, jirata and mao had lower root densities. The root densities obtained for the different *anchote* accessions in the current study were generally lower than those reported for cassava (Oriola and Rajii, 2013). The densities of *anchote* roots are fairly comparable to those reported for cocoyam (Balami*et al*., 2012b) and sweet potato roots (Balami*et al.,* 2012a).

3.1.2. Effects of growing area on the physical properties of *anchote*

The growing area of *anchote* roots significantly influenced ($p<0.05$) the minor diameter, root peel thickness and peel to root ratio (Table 1). The roots grown at Hawassa site had significantly higher minor diameter and aspect ratio, while those of Wondo Genet site had higher root peel thickness and peel to root ratio. Since the peels are not edible parts of the roots, the higher peel thickness and peel to root ratio associated to Wondo Genet growing site indicates poor yield of the edible portion of the roots.

3.1.3. Interaction effects of Growing area and accessions on the physical properties of *anchote*

The combined effect of the different accessions and the growing areas was also observed to be significant ($p<0.05$) (Table 3). Gute accession grown at Wondo Genet site had the highest major diameter, while there was no significant difference among the major diameters of the other accessions grown at both sites. The least minor diameter corresponded to the jirata accession grown at Wondo Genet site, while there was no clear segregation among the means of the remaining accessions grown at both experiment sites. Regarding the influence of the accessions and growing areas on the shape (aspect ratio) of the roots, higher values (irregularity in shape) were observed for alukawusa and jirata accessions grown at Wondo Genet site. Lower aspect ratios (better roundness) were recorded for dicho accession grown at both sites. Similarly, hagallo and jirata accessions grown at Wondo Genet and Hawassa sites, respectively, had lower aspect ratios.

The peel thickness of the *anchote* root accessions grown at both sites was observed to be significantly influenced ($p<0.05$) (Table 3). The least peel thickness (better quality) was observed for the dicho accession regardless of the growing sites. Clear segregation among the means of the peel thickness of the other accessions grown at the two sites was not observed.The peel thickness obtained for the *anchote* roots in the current research is generally higher than those reported for cassava (Oriola and Rajii, 2013).

The peel to root ratio (w/w) and the root density were also significantly influenced ($p<0.05$) by the interaction of the accessions with the growing site. Higher root densities were recorded for the ago accession grown at Hawassa site and jimate grown at both sites. Lower root densities corresponded to gute and mao accessions grown at Hawassa and Wondo Genet sites, respectively. The root density indicates the compactness of the starchy mass (Figure 3) and can be associated to better energy content. Root density of the *anchote* accessions obtained in the current study is higher than (almost double) those reported for sweet potato (Teye and Abamo, 2012), but comparable with those reported for cocoyam (Balami *et al*., 2012b)and cassava (Oriola and Rajii, 2013).

Figure 6: The integrity of *anchote* root

Table 4: Effect of growing area on physical properties of *anchote* roots

Growing area	**Diameter (mm)**		**Aspect Ratio**	**Peel thickness (mm)**	**Peel to root ratio (w/w)**	**Root density (kgm^{-3})**
	Major	**Minor**				
Hawassa	92.57±19.11^{a}	79.81±10.56^{a}	1.22±0.20^{a}	1.80±0.32^{b}	0.13±0.026^{b}	1020.80±102.12^{a}
Wondo Genet	120.67±167.71^{a}	71.08±12.98^{b}	1.32±0.36^{a}	1.95±0.27^{a}	0.17±0.03^{a}	1014.75±43.34^{a}

Table 5: Combined effect of Accessions and growing areas on physical properties of *anchote* roots

Variables		**Diameter (mm)**		**Aspect Ratio**	**Peel thickness (mm)**	**Peel to root ratio (w/w)**	**Root density (kgm^{-3})**
Accessions	**Growing Area**	**Major**	**Minor**				
Ago	Hawassa	95.39±5.79^{b}	72.99±4.27^{bcdef}	1.31±0.16^{bcd}	1.74±0.61^{bcde}	0.13±0.01^{d}	1202.83±187.85^{a}
Ago	Wondo Genet	99.43±12.16^{b}	84.04±10.47^{abcd}	1.20±0.27^{bcd}	1.76±0.04^{bcde}	0.14±0.03^{bcd}	1024.36±23.89^{bcd}
Alukawusa	Hawassa	106.73±2.18^{b}	82.52±12.88^{abcde}	1.31±0.17^{bcd}	1.64±0.24^{de}	0.14±0.02^{bcd}	998.49±13.22^{bcde}
Alukawusa	Wondo Genet	95.09±13.01^{b}	51.42±7.99^{g}	1.89±0.45^{a}	2.13±0.11^{ab}	0.18±0.06^{abc}	987.97±4.87^{bcde}
Choli Michael	Hawassa	87.09±10.09^{b}	67.60±4.59^{ef}	1.29±0.15^{bcd}	1.90±0.14^{abcde}	0.13±0.04^{d}	1013.94±53.01^{bcde}
Choli Michael	Wondo Genet	107.96±24.39^{b}	87.76±17.25^{ab}	1.30±0.56^{bcd}	2.04±0.07^{abcd}	0.17±0.05^{abcd}	1036.65±13.83^{bcd}
Dicho	Hawassa	92.40±6.12^{b}	94.55±14.64^{a}	0.99±0.17^{d}	1.47±0.21^{e}	0.13±0.00^{d}	1025.79±8.97^{bcd}
Dicho	Wondo Genet	77.91±6.83^{b}	73.61±5.98^{bcdef}	1.06±0.05^{d}	1.54±0.11^{e}	0.12±0.03^{d}	1014.49±12.50^{bcde}
Gimbi 01	Hawassa	106.26±5.39^{b}	73.59±11.34^{bcdef}	1.47±0.31^{bc}	2.01±0.19^{abcd}	0.12±0.01^{d}	998.01±11.73^{bcde}
Gimbi 01	Wondo Genet	74.49±8.17^{b}	68.31±8.34^{def}	1.10±0.19^{cd}	1.98±0.35^{abcd}	0.19±0.00^{ab}	991.20±3.47^{bcde}
Gute	Hawassa	93.58±4.21^{b}	84.09±6.93^{abcd}	1.12±0.15^{cd}	1.78±0.40^{abcde}	0.14±0.05^{bdc}	914.42±127.88^{e}
Gute	Wondo Genet	393.42±529.21^{a}	74.15±13.33^{bcdef}	1.26±0.19^{bcd}	2.21±0.32^{a}	0.17±0.01^{abcd}	1019.87±28.49^{bcde}
Hagallo	Hawassa	71.63±53.26^{b}	85.30±1.97^{abc}	1.23±0.17^{bcd}	1.71±0.38^{bcde}	0.13±0.03^{d}	983.28±54.30^{bcde}
Hagallo	Wondo Genet	70.26±8.02^{b}	68.84±11.06^{def}	1.02±0.07^{d}	1.64±0.16^{de}	0.16±0.01^{abcd}	1052.58±63.93^{bcd}
Jimate	Hawassa	107.61±13.53^{b}	80.45±6.71^{abcde}	1.33±0.07^{bcd}	2.03±0.36^{abcd}	0.13±0.00^{d}	1085.10±104.79^{b}
Jimate	Wondo Genet	91.13±1.56^{b}	69.47±10.93^{cdef}	1.33±0.20^{bcd}	2.05±0.28^{abcd}	0.15±0.01^{bcd}	1066.95±59.66^{bc}
Jirata	Hawassa	77.46±3.40^{b}	77.94±13.59^{bcdef}	1.01±0.12^{d}	1.99±0.07^{abcd}	0.15±0.06^{bcd}	975.83±41.14^{cde}
Jirata	Wondo Genet	100.19±18.83^{b}	63.82±7.77^{fg}	1.60±0.44^{ab}	2.09±0.07^{abc}	0.21±0.02^{a}	1000.25±8.99^{bcde}
Mao	Hawassa	87.52±4.49^{b}	79.09±4.48^{abcdef}	1.11±0.06^{cd}	1.68±0.23^{cde}	0.12±0.00^{d}	1010.30±30.36^{bcde}
Mao	Wondo Genet	96.78±17.44^{b}	69.36±2.86^{cdef}	1.39±0.20^{bcd}	2.12±0.12^{ab}	0.17±0.04^{abcd}	953.21±52.06^{de}

3.2. Proximate composition of *Anchote*

3.2.1. Effects of accessions on proximate composition of *anchote*

The proximate compositions of *anchote* accessions are significantly different (p<0.05) (Table 4). The moisture contents of the *anchote* accessions were in the range of 6.85 and 9.74% which supports for suppression of microbial growth (Beruk *et al.*, 2013). This result is in line with moisture contents (7.60%) of maize flour (Kavitha and Parimalavalli, 2014). In similar fashion, the crude proteins of the accessions were in the range of 5.07 and 6.08% and higher values corresponded to jimmate, dicho, gimbi 01 and hagello accessions. Ago, gute and jirata on the other hand, exhibited lower levels of protein. The protein content of *anchote* is reported to be fairly higher than protein contents of other common edible roots such as sweet potato (1.4%), cassava (0.5%), yam (2.0%) and taro (1.1%) (Bradbury and Holloway, 1988). Crude fiber contents of the ten accessions in this study were between 4.77 and 7.93% and higher crude fiber levels corresponded to ago and jimate. Alukawusa, hagello and jirata accessions were the ones with lower levels of crude fiber contents.The crude fiber content of anchote accessions tested in this research is generally higher than that of potato (2.2%), carrot (2.8%) and is comparable with that of corn (7.3%) (Montagnac *et al*., 2009). This is due to the fibrous nature of *anchote* root compared to other fibrous crops like kocho (*enset*) (3.37%), cassava (1.5%), and taro (3.9%) (Bradbury and Holloway, 1988; Yirmaga, 2013).

The crude fat contents of the *anchote* were significantly influenced by the accessions. The crude fat content ranged between 3.53% and 4.77%. This result is comparable with fat contents of maize (4.36% and 4.74%), higher than that of wheat (1.92%), potato (0.09%), cassava (0.03 to 0.05%), *enset* (1.04 to 1.27%) (Montagnac *et al.*, 2009; Yirmaga, 2013; Kavitha and Parimalavalli, 2014). Mao was the accessions with the least ($p<0.05$) value of crude fat content. The ash contents of *anchote* accessions in this study were in the range of 5.46 (gimbi 01) to 7.59% (jirrata). This result is higher than ash contents of wheat, maize, groundnut, potato, carrot, guinea yam, *enset* and cocoyam (Montagnac *et al.*, 2009; Yirmaga, 2013; Ihediohanma *et al*., 2014; Kavitha and Parimalavalli, 2014). But it is comparable with *enset* grown (7.47 to 8.17%) in Hawassa area (Mohammed *et al*., 2013). This might be due to difference in the agro-ecology and soil minerals nutrient contents (Adane *et al.*, 2013). The carbohydrate contents of *anchote* accessions were in the range of 74.10 (jirrata) to 77.25% (choli michael). This result is lower than carbohydrate contents of cocoyam (79.14-79.75%), but it is higher than that of sweet potato (25.74%), *enset* (32.75-35.53%), guinea yam (69.50%) and cassava (25.3-35.7%) (Montagnac *et al.*, 2009; Yirmaga, 2013; Ihediohanma *et al.*, 2014). This might be associated to higher moisture contents, which decrease the proportions of other proximate values. The gross energy of *anchote* accessions in this study were in the range of 356.10 and 371.33kcal. The result is comparable with the energy of corn (365kcal) and mung bean (342.36 to 373.34kcal) (Montagnac *et al*., 2009; Blessing and Gregory, 2010).

3.2.2. Effects of growing area on the proximate composition of *anchote*

The effects of growing area on some components of proximate composition of *anchote* was significant ($p<0.05$) (Table 5). The crude protein, crude fiber, total ash and gross energy of *anchote* roots were significantly different due to growing sites (Hawassa and Wondo Genet). Higher levels of crude protein, crude fiber and gross energy corresponded to *anchote* roots grown in Wondo Genet, whereas higher ash content was associated to the *anchote* roots grown in Hawassa. The difference is due to variation in agro-ecology of the two areas as described under section 2.1. Similar situation was reported for *Moringa olifera* in Ghana by Asante *et al.,* (2014).

Table 6: Effect of Accessions on proximate composition of *anchote* roots

Accessions	Moisture content (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	Ash (%)	Total carbohydrate (%)	Gross energy (%)
Ago	8.79±0.28^{abc}	5.07±1.34^{e}	7.93±0.82^{a}	4.77±0.39^{a}	6.14±0.43^{bc}	75.24±1.60^{bcd}	364.12±2.6970^{bc}
Alukawusa	7.75±2.91^{cd}	5.62±0.38^{bcd}	6.04±0.29 d^{e}	4.67±0.08^{ab}	5.47±0.39^{d}	76.50±3.03^{ab}	370.47±13.40^{ab}
Choli Michael	6.85±1.48^{d}	5.56±0.70^{bcd}	6.08±0.50^{cde}	4.48±0.16^{abc}	5.86±0.15^{cd}	77.25±2.18^{a}	371.56±4.61^{a}
Dicho	9.29±1.72^{ab}	5.91±0.14^{ab}	6.60±2.67^{bcd}	4.72±0.55^{ab}	5.88±0.22^{cd}	74.21±2.29^{cd}	362.92±5.26^{cd}
Gimbi 01	7.42±0.68^{cd}	5.75±0.64^{abc}	6.13±1.92^{cde}	4.57±1.10^{ab}	5.46±0.33^{d}	76.81±1.26^{ab}	371.33±4.01^{a}
Gute	9.44±0.46^{ab}	5.33±0.36^{de}	6.99±1.85^{bc}	4.18±0.28^{dc}	5.69±0.26^{cd}	75.37±1.15^{bcd}	360.39±1.69^{cd}
Hagallo	9.74±0.79^{a}	5.78±0.47^{abc}	4.77±0.45^{f}	4.41±0.05^{bc}	5.91±0.77^{cd}	74.16±0.52^{cd}	359.47±2.35^{cd}
Jimate	8.56±0.05^{abc}	6.08±0.42^{a}	7.37±1.26^{ab}	3.95±0.08^{d}	5.53±0.34^{d}	75.89±0.22^{abc}	363.39±1.59^{c}
Jirata	8.66±0.90^{abc}	5.44±0.46^{cde}	5.31±0.44^{ef}	4.22±0.57^{dc}	7.59±2.44^{a}	74.10±1.47^{d}	356.10±9.19^{d}
Mao	8.10±0.95^{bcd}	5.66±0.57^{bcd}	6.74±1.30^{bcd}	3.53±0.11^{e}	6.52±1.00^{b}	76.19±1.25^{ab}	359.16±3.35^{cd}

Table 7: Effect of growing area on proximate composition of *anchote* roots

Accessions	Moisture content (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	Ash (%)	Total carbohydrate (%)	Gross energy (%)
Hawassa	8.46±1.40^{a}	5.41±0.64^{b}	5.92±1.56^{b}	4.37±0.62^{a}	6.50±1.22^{a}	75.26±2.03^{a}	362.04±7.74^{b}
Wondo Genet	8.46±1.52^{a}	5.83±0.53^{a}	6.87±1.32^{a}	4.32±0.48^{a}	5.51±0.32^{b}	75.88±1.64^{a}	365.74±6.86^{a}

3.2.3. Interaction effects of growing area and accessions on the proximate composition of *anchote*

The interaction effect of *anchote* accessions and growing sites on proximate composition was statistically significant ($p<0.05$) (Table 6). The moisture contents of dried *anchote* were between 5.57 (choli michael from Hawassa) and 10.77% (dicho from Hawassa) and comparable with the levels reported for breadfruit (6.83%), soybean (5.11%), mung bean (10.25%), water yam (6.7%), yam (6.22 to 6.9%), African yam bean (9.43%), green gram (10.9%), cowpea (8.5%), chickpea (9.9%) and maize (6.92-8.27%) (Ijarotimi and Arege, 2005; Gurita, 2006; Ghavidel and Prakash, 2007; Blessing and Gregory, 2010; Ezeocha and Ojimelukwe, 2012; Ukom *et al.*, 2014).

The protein contents of *anchote* accessions grown in both areas were between 3.91 (ago grown from Hawassa) and 6.44% (Jimmate from Wondo Genet) and these were generally higher than those reported for *enset* (3.17 to 3.65%), breadfruit (1.88%), cassava (0.3 to 3.5%), potato (2.02%), yam (2.0%), taro (1.1%), sweet potato (1.4%) and carrot (0.93%) (Bradbury and Holloway, 1988; Ijarotimi and Arege, 2005; Montagnac *et al.*, 2009; Mohammed *et al.*, 2013; Yirmaga, 2013). The fiber contents obtained for *anchote* in this study were between 4.28% and 8.91% in dicho accessions grown in Hawassa and Wondo Genet respectively. This is comparable with the fibers of corn (7.3%), sweet potato (5.3%), soybean (4.90%) and mung bean (5.0%) (Bradbury and Holloway, 1988; Ijarotimi and Aroge, 2005; Montagnac *et al.*, 2009; Blessing and Gregory, 2010). But it is higher than those of wheat (1.51%), cassava (0.1 to 3.7%), taro (2.63%) and groundnut (2.70%) (Montagnac *et al.*, 2009; Adane *et al,* 2013; Kavitha and Parimalavalli, 2014).The fat contents of *anchote* accessions growing at the two sites was within the range of 3.44 to 5.42%. Comparable result was observed for sorghum (2.87 to 3.85%) and maize (4.47%) (Liu *et al*., 2012; Katari, 2014). But it is higher than fat contents of cassava (0.03 to 0.5%), taro (0.47%) and potato (0.09%) (Montagnac *et al.*, 2009; Adane *et al*, 2013). The ash contents of *anchote* accessions grown in both areas were in between 5.18 and 9.70%. This result is comparable with that reported for *enset* (7.47 to 8.17%, 3.07 to 11.55%) (Solomon *et al*., 2008; Mohammed *et al.*, 2013). But it is higher than that of taro (4.83%), maize (1.34%) and cassava (2.43 to 3.45%) (Tilahun, 2009; Adane *et al.*, 2013; Kavitha and Parimalavalli, 2014). Similarly, the total carbohydrate contents were in the range of 72.25 to 79.14%. This result is in line with findings for groundnut (79.01%), cocoyam (79.14 to 79.75%), rice (77.81%) and water yam (76.57%) (Ezeocha and Ojimelukwe, 2012; Ihediohanma *et al.*, 2014; Kavitha and Parimalavalli, 2014). The energy contents of *anchote* accessions grown in both Hawassa and Wondo Genet areas were between 348.23 to 377.42kcal. The result is comparable with taro (372.55kcal), cassava (376.86 to 386.55kcal) and water yam (357.65kcal) (Tilahun, 2009; Ezeocha and Ojimelukwe, 2012; Adane *et al.*, 2013).

Table 8: Combined effect of accessions and growing areas on proximate composition of *anchote* roots (%dw)

Variables		**Moisture content (%)**	**Crude protein (%)**	**Crude fiber (%)**	**Crude fat (%)**	**Ash (%)**	**Total carbohydrate (%)**	**Gross energy (%)**
Accessions	**Growing Area**							
Ago	Hawassa	8.55 ± 0.07^{bcde}	3.91 ± 0.06^{h}	8.64 ± 0.04^{a}	4.43 ± 0.13^{cd}	6.49 ± 0.24^{c}	76.62 ± 0.13^{bcd}	361.99 ± 1.88^{de}
Ago	Wondo Genet	9.02 ± 0.09^{abcde}	6.23 ± 0.04^{ab}	7.22 ± 0.04^{bcd}	5.10 ± 0.00^{ab}	5.79 ± 0.06^{def}	73.86 ± 0.01^{fgh}	366.26 ± 0.11^{bcde}
Alukawusa	Hawassa	9.16 ± 0.08^{abcd}	5.31 ± 0.20^{efg}	5.90 ± 0.42^{ef}	4.60 ± 0.01^{c}	5.71 ± 0.14^{ef}	75.23 ± 0.42^{defg}	363.52 ± 0.84^{cde}
Alukawusa	Wondo Genet	6.34 ± 4.19^{fg}	5.93 ± 0.06^{abcd}	6.18 ± 0.03^{def}	4.74 ± 0.00^{bc}	5.23 ± 0.45^{f}	77.76 ± 4.58^{abc}	377.42 ± 18.5^{a}
Choli Michael	Hawassa	5.57 ± 0.09^{g}	4.95 ± 0.01^{g}	5.75 ± 0.07^{efg}	4.35 ± 0.07^{cde}	5.99 ± 0.03^{cde}	79.14 ± 0.06^{a}	375.53 ± 0.83^{ab}
Choli Michael	Wondo Genet	8.13 ± 0.10^{cdef}	6.17 ± 0.04^{abc}	6.40 ± 0.57^{cde}	4.61 ± 0.06^{c}	5.73 ± 0.03^{ef}	75.37 ± 0.23^{cdef}	367.59 ± 0.19^{bcde}
Dicho	Hawassa	10.77 ± 0.03^{a}	5.80 ± 0.06^{bcdef}	4.28 ± 0.03^{h}	5.14 ± 0.09^{ab}	6.05 ± 0.07^{cde}	72.25 ± 0.12^{h}	358.42 ± 0.03^{e}
Dicho	Wondo Genet	7.80 ± 0.28^{cdef}	6.03 ± 0.04^{abc}	8.91 ± 0.06^{a}	4.29 ± 0.41^{cde}	5.71 ± 0.14^{ef}	76.17 ± 0.59^{bcdef}	367.41 ± 1.49^{bcde}
Gimbi 01	Hawassa	7.82 ± 0.17^{cdef}	5.30 ± 0.28^{fg}	4.56 ± 0.01^{gh}	5.42 ± 0.81^{a}	5.73 ± 0.07^{ef}	75.73 ± 0.28^{bcdef}	372.90 ± 4.99^{abc}
Gimbi 01	Wondo Genet	7.02 ± 0.85^{efg}	6.20 ± 0.57^{ab}	7.69 ± 1.10^{abc}	3.71 ± 0.16^{fg}	5.18 ± 0.13^{f}	77.89 ± 0.00^{ab}	369.75 ± 3.66^{abcd}
Gute	Hawassa	9.80 ± 0.35^{abc}	5.63 ± 0.18^{cdef}	5.81 ± 2.16^{fg}	4.30 ± 0.42^{cde}	5.77 ± 0.03^{def}	74.51 ± 0.93^{defgh}	359.24 ± 0.85^{e}
Gute	Wondo Genet	9.08 ± 0.04^{abcd}	5.03 ± 0.03^{g}	8.16 ± 0.23^{ab}	4.05 ± 0.01^{def}	5.60 ± 0.42^{ef}	76.24 ± 0.34^{cdef}	361.53 ± 1.60^{de}
Hagallo	Hawassa	9.06 ± 0.04^{abcde}	6.19 ± 0.12^{ab}	4.50 ± 0.57^{gh}	4.41 ± 0.06^{cd}	6.40 ± 0.71^{cd}	73.95 ± 0.73^{efgh}	360.21 ± 2.94^{de}
Hagallo	Wondo Genet	10.41±0.057 ab	5.38 ± 0.11^{efg}	5.04 ± 0.04^{fgh}	4.41 ± 0.07^{cd}	5.42 ± 0.57^{ef}	74.38 ± 0.33^{defgh}	358.73 ± 2.39^{e}
Jimate	Hawass	8.56 ± 0.09^{bcd}	5.72 ± 0.03^{bc}	8.37 ± 0.88^{a}	3.91 ± 0.04^{f}	5.81 ± 0.14^{d}	76.00 ± 0.24^{bc}	362.07 ± 0.69^{d}

	a	^{e}	^{def}	^{b}	^{g}	^{ef}	^{def}	^{e}
Jimate	Wondo Genet	8.56±0.01^{bcde}	6.44±0.06^{a}	6.37±0.10^{de}	3.98±0.11^{def}	5.24±0.057^{f}	75.78±0.21^{bcdef}	364.70±0.40^{cde}
Jirata	Hawassa	7.90±0.353^{cdef}	5.83±0.03^{bcdef}	5.68±0.17^{efg}	3.73±0.06^{fg}	9.70±0.14^{a}	72.85±0.40^{gh}	348.23±2.30^{f}
Jirata	Wondo Genet	9.41±0.00^{abcd}	5.05±0.14^{g}	4.93±0.04^{fgh}	4.71±0.03^{bc}	5.49±0.01^{ef}	75.35±0.16^{cdef}	363.97±0.17^{cde}
Mao	Hawassa	7.42±0.83^{defg}	5.46±0.65^{def}	5.66±0.01^{efg}	3.44±0.01^{g}	7.30±0.57^{b}	76.38±2.07^{bcde}	358.32±5.53^{e}
Mao	Wondo Genet	8.79±0.39^{abcde}	5.85±0.64^{bcde}	7.82±0.61^{ab}	3.62±0.01^{fg}	5.74±0.51^{ef}	76.01±0.50^{bcdef}	360.00±0.41^{de}

4.0 Conclusion

The different *anchote* accessions and growing sites yielded significantly different physical properties [root size in terms of major and minor diameters, root roundness (shape) in terms of aspect ratio, root peel thickness, peel proportion to root (w/w) and root densities]. Over all, better quality, in terms root peel thickness and peel to root ratio, were observed for the accessions grown at Hawassa.

Similarly statistically different proximate compositions were observed due to the separate and combined effects of accession types and growing sites. The *anchote* accessions grown at Wondo Genet site were observed to have higher levels of crude protein, crude fiber and gross energy than those grown at Hawassa. Higher ash content was associated to the accessions grown at Hawassa site.

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References

Abera, G. and Gudeta, H. (2007).Response of *Anchote* (*Cocciniaabyssinica*) to Organic and Inorganic Fertilizers Rates and Plant Population Density in Western Oromia, Ethiopia.*East African Journal of Sciences,* 1 (2): 120-126.

Adane, T., Shemelis, A., Nigussie, R., Tilahun, B. and Haki, G.D. (2013).Effect of Processing Method on the Proximate Composition, Mineral Content and Anti-nutritional Factors of Taro (*Colacasiaesculenta*, L.)Grown in Ethiopia. African Journal of Food, Agriculture, Nutrition and Development, 13(2):7383-7398.

Ademosun, O. C., Jimoh, M. O. and Olukunle O. J. (2012).Effect of physical and mechanical properties of cassava tubers on the performance of an automated peeling machine.*International Journal of Development and Sustainability,* 1 (3): 810-822.

Amare G., (1976). Some Common Medicinal And Poisonous Plants Used in Ethiopian Folk Medicine. Addis Ababa University.

Amare, G., (1973). Developmental Anatomy of Tuber of Anchote, A Potential Dry Land Crop. Proceedings of the First Ethiopian Horticultural Workshop, February 20-23, 1985, Addis Ababa, Ethiopia, Pp: 313-323.

AOAC (Association of Official Analytical Chemists), (1995) Official Methods of Analysis.16th ed. Vol.I and II, Virginia, USA.

Asante, W.J., Nasare, I.L., Tomy-Dery, D., Ochire-Buadu,K. and Kentil, K.B. (2014). Nutritional Composition of *Moringaoleifera* Leaves from two Agro ecological zones in Ghana. African Journal of Plant Science, 8(1):65-71.

Atwater W. O. and Benedict F. G. (1902).Experiments on the metabolism of matter and energy in the human body, 1898–1900.US Office of Experiment Stations Bulletin No. 109, Government Printing Office, Washington, DC.

Balami, A. A., Adebayo, S. E. and Adetoye, E. Y. (2012a).Determination of some engineering properties of sweet potato (Ipomoea batatas).*Asian Journal of Natural and Applied Sciences,* 1(1): 67-77.

Balami, A. A., Mohammed, I. A., Adebayo, S. E., Adgidzi, D. and Adelemi, A. A. (2012b).The relevance of some engineering properties of cocoyam (*Colocasiaesculenta*) in the design of postharvest processing machinery.*Academic Research International,* 2(3): 104-113.

Bekele, F., Abera, B., and Getahun, M. (2013).*In vitro* propagation of Anchote (*Cocciniaabyssinica)* (Lam.) Cogn.].*African Journal of Plant Science,* 7(6): 253-264.

Bekele, T., Kassa, K., Mengistu, T., Debele, M. and Melka, Y. (2013). Working with communities to address deforestation in the Wondo Genet Catchment Area, Ethiopia: Lessons learnt from a participatory action research. *Research Journal of Agriculture and Environmental Management*, 2(12): 448-456.

Beruk, B. D., Abegaz, K. and Kinfe, E. (2015). Effect of Blending Ratio and Processing Technique on Physicochemical Composition, Functional Properties and Sensory Acceptability of Quality Protein Maize (QPM) Based Complementary Food. *International Journal of Food Science and Nutrition Engineering,* 5(3): 121-129.

Blessing, I.A. and Gregory, I.O. (2010).Effect of Processing on the Proximate Composition of the Dehulled and un-DehulledMung bean [*Vigna radiate* (L.)Wilczele) Flours.*Pakistan Journal of Nutrition, 9(10):1006-1016.*

Bradbury, J.H. and Holloway, W.D. (1988). Chemistry of Tropical Root Crops: Significance for Nutrition and Agriculture in the Pacific. ACIAR Monograph No.6 Pp. 201, Canberra, Australia.

Dawit A. And Estifanos H. (1991).Plants as a Primary Source of Drugs in the Traditional Health Practices of Ethiopia. In: Engels, J.M.M., Hawkes, J.G and MelakuWorede (Eds.), Plant Genetic Resources of Ethiopia. Cambridge University Press.

Ezeocha, V.C. and Ojimelukwe, P.C. (2012). The Impact of Cooking on the Proximate and Anti-nutritional Factors of Water yam (*Dioscoreaalata*). Journal of Stored Products and Postharvest Research, 3(3):172-176.

Fekadu H. (2011). Nutritional And Anti-Nutrition's Of Anchote (CocciniaAbyssinica) Tubers: LAP LAMBERT Academic Publishing, Addis Ababa Ethiopia. Pp.124.

Fekadu, H., Beyene, F. and Desse, G. (2013).Effect of Traditional Processing Methods on Nutritional Composition and Anti-nutritional Factors of Anchote (CocciniaAbyssinica (lam.)Cogn) Tubers Grown in Western Ethiopia.*Journal of Food Process Technology,* 4(7), 1-8.

Food and Agricultural Organization (FAO) of the United Nations (2013).(http://www.fao.org/wairdocs/tac/x5791e/x5791e0q.htm#introduction, (accessed on 10, June 2013).

Ghavidel, R.A. and Prakash, J. (2007). The Impact of Germination and Dehulling on Nutrients, Anti-nutrients, In vitro Iron and Calcium Bioavailability and In vitro Starch and Protein Digestibility of some legume Seeds. *LWT, 40:1292-1299.*

Gurita, P. (2006). Physico-chemical Properties, Nutritional Quality and Value Addition to Quality Protein Maize (Zea mays L.). MSc Thesis, University of Agricultural Sciences, Dharwad,pp70.

Ihediohanma, N.C., Okafor, D.C., Osuagwu, P. U and Onuegbu, N.C. (2014).Proximate Composition and Carotene Content of Three Cultivars of *Xanthosomasagittifolium.IOSR Journal of Environmental Science, Toxicology and Food Technology, 8(2):17-22.*

Ijarotimi, S.o. and Aroge, F. (2005). Evaluation of the Nutritional Composition, Sensory and Physical Properties of a Potential Weaning Food from Locally Available Food Materials-Breadfruit (*Artocarpusaltilis*) and Soybean (*Glycine max*). *Polish Journal of Food and Nutrition Sciences, 14(4):411-415.*

Kassa, D. and Bekele, A. (2008).Species composition, abundance, distribution and habitat association of rodents of Wondo Genet, Ethiopia.*SINET: Ethiopian Journal of Science, 31(2):141–146.*

Katari, R. (2014). Proximate Nutritional Evaluation of Maize and Rice-Gluten Free Cereal.*IOSR Journal of Nursing and Health Sciences, 3(2):01-06.*

Kavitha, S. and Parimalavalli, R. (2014).Effect of Processing Methods on Proximate Composition of Cereal and Legume flours.*Journal of Human Nutrition and Food Science 2(4): 1-5.*

Liu, L., Herald, T.J., Wang, D., Wilson, J.D., Bean, S.R. and Aramouni, F.M. (2012).Characterization of Sorghum Grain and Evaluation of Sorghum Flour in a Chinese Egg Noodle System.http://digitalcommons.unl.edu/usdaarsfacpub/858.

Maduako, J.N.,&Faborode, M.O. (1990). Some physical properties of cocoa pods in relation to primary processing.*Ife Journal of Technology, 2,* 1–7.

Mekuria, S., Misganaw, E. and Abebe, R. (2014).Epidemiological Survey on Small Ruminant Fasciolosis in

HawassaZuria and Dale Districts, Sidama Zone, Southern Ethiopia. *African Journal of Basic & Applied Sciences,* 6 (2): 43-49.

Mengesha, D., Belew, D., Gebrasillasie, W., Sori, W. (2012). Growth and Yield Performance of *Anchote.Asian Journal of Plant Sciences*, 11:172-181.

Mohammed, B., Gabel, M. and Karlsson, L.M. (2013).Nutritive Values of the Drought Tolerant Food and Fodder Crop *Enset.African Journal of Agricultural Research, 8(20):2326-2333.*

Montagnac, J.A., Davis, C.R. and Tanumihardjo.S.A.(2009).Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement.*Comphrensive Reviews in Food Science and Safety*, 8:181-194.

Oriola, K. and Raji, A. (2013).Effects of Tuber Age and Variety on Physical Properties of Cassava [*ManihotEsculenta* (Crantz)] Roots.*Innovative Systems Design and Engineering,* 4(9): 15-25.

Sahin, S. And Sumnu, S. G., (2006) Physical Properties Of Foods, Pp. 1-8, Springer Science Business Media, LLC, New York, USA.

Solomon, Z., Olsson,M. and Fetene, M. (2008). Effect of Drought/Irrigation on Proximate Composition and Carbohydrate Content of Two Enset (*Ensetventicosum* (Welm.)Cheesman) Clones.*SINET:Ethiopian Journal Science, 31(2):81-88.*

Tadesse, F. T., Nigusse, G. and Kurabachew, H. (2015). Nutritional, Microbial and Sensory Properties of Flat- Bread Prepared from blends of Maize *(Zea mays L.)* and Orange-Fleshed Sweet Potato *(Ipomoea batatas L.)* Flours.*International Journal of Food Science and Nutrition Engineering,* 5(1): 33-39.

Teye, E. and Abano, E. E. (2012).Physical properties of two varieties of sweet potato grown in coastal savannah zone of Ghana.*International Journal of Science and Nature,* 3(1): 105-109.

TilahunAbera. (2009). Effect of Processing on some Physicochemical Composition and Anti-nutritional Factors of Locally Grown Cassava (*Manihotesculenta*Crantz) Varieties.MSc Thesis, Addis Ababa University, pp88.

Ukom, A.N., Ojielukwe, P.C., Ezeama, C.F., Ortiz, D.O. and Aragon, I.I. (2014).Proximate Composition and Carotenoid Profile of Yams (*Dioscorea spp*.) and cocoyam (*Xanthosomamaffa* (Scoth)) Root Tubers from Nigeria.*American Journal of Food and Nutrition, 4(11):1-10.*

Wondrade, N., Dick, O. B. and Tveite, H. (2014).Landscape Mapping to Quantify Degree-of-Freedom, Degree-of-Sprawl, and Degree-of-Goodness of Urban Growth in Hawassa, Ethiopia.*Environment and Natural Resources Research*, 4(4): 223-237.

Yambo, Y. and Feyissa, T. (2013).Micropropagation of anchote [*Cocciniaabyssinica*(Lam.) Cogn.]: High calcium content tuber crop of Ethiopia. *African Journal of Agricultural Research,* 8(46): 5915-5922.

Yassin, H., Mohammed, A., Fekadu, D. and Hussen, S. (2013). Effect of Flower Bud Removal on Growth and Yield of Anchote Root (*Cocciniaabyssinica*(Lam.) Cogn.)Accessions at Bishoftu.*Advanced Research Journal of Plant and Animal Sciences,* 1(1): 7-13.

Yirmaga,M.T. (2013). Improving the Indigenous Processing of Kocho, an Ethiopian Traditional Fermented Food. *Journal of Nutrition and Food*, 3(1):1-6.