Food Value of Native and Non-Native Tree Species in Tigray, Northern Ethiopia

ABSTRACT

Indigenous and adopted food-bearing trees play a crucial role in ensuring food security during food shortages and on a daily basis in rural and urban communities in Tigray. However, information on their nutritional composition is still lacking. The objective of this study was to assess the macronutrient and mineral content of the most commonly used indigenous and adopted food trees. Fruit samples were selected based on their degree of maturation, health, and disease-free status. Three samples per plant species were collected and analyzed at the Ethiopian Health and Nutritional Research Institute laboratory. The results revealed that protein content was highest in *Ximenia americana* (8.04 ± 1.1%), followed by *Cordia africana* (5.09 ± 0.9%) and *Ficus sycomorus* (4.63 ± 1.0%), with the lowest protein content found in *Adansonia digitata* (2.02 ± 0.8%) and *Hyphaene thebaica* (2.44 ± 1.7%). Crude fiber and fat content were highest in *Tamarindus indica*, with fat content also being highest in *Ficus sycomorus*. *Adansonia digitata* had the lowest ash content, while *Syzygium guineense* had the highest moisture content. *Ficus sycomorus* fruits contained the highest levels of iron (56.5 ± 5.0 mg/100g), calcium (584.3 ± 14.0 mg/100g), and copper (0.9 ± 0.1 mg/100g), while zinc levels were lower in *Hyphaene thebaica* and higher in *Ficus sycomorus*. The potassium and phosphorus contents varied among the species, with *Tamarindus indica* having 3030.3 mg of potassium and 30.9 mg of phosphorus, *Ximenia americana* having 2704.0 mg of potassium and 106.6 mg of phosphorus, and other species showing varying amounts. Higher total carbohydrate content was found in *Adansonia digitata* (71.76%), *Hyphaene thebaica* (63.31%), *Tamarindus indica* (62.79%), and *Cordia africana* (59.28%). The highest energy values (347.2, 283.4, 264.2, and 258.4 kcal/100g) were observed in *Tamarindus indica*, *Cordia africana*, *Hyphaene thebaica*, and *Syzygium guineense*, respectively. In conclusion, wild and semi-wild edible trees are essential for addressing food shortages and have the potential to combat nutrient deficiencies in the region.

Keywords: Indigenous, macronutrient, minerals and nutritional

Introduction

Millions of people in many developing countries rely on wild resources, including wild and semi-wild edible plants, to meet their food needs during times of food crisis (Balemie and Kebebew, 2006). In Ethiopia, there are approximately 370 indigenous food plants, belonging to 70 different families, of which 182 species (from 40 families) are shrubs or trees with edible fruits or seeds. Previous studies have shown that about 8% of Ethiopia's nearly 7,000 higher plant species are edible (Feyssa et al., 2011). Of these, 203 wild and semi-wild plant species were documented (Zemede et al., 2011), with many more believed to be edible but still undocumented. More recent ethnobotanical studies have been conducted in some parts of the country, but most have focused on medicinal species, with little emphasis on wild edible and semi-wild plants.

In the Tigray region, many people rely on wild edible plants as a supplementary food source during drought seasons and times of hardship (Mulugeta *et al.* (2010). This highlights the potential of wild edible plants to substitute for a variety of crops during droughts and demonstrates their importance in food security. According to Mulugeta et al. (2010), there is a chronic malnutrition problem in Tigray, with low energy and nutrient density in complementary foods, which are typically made from a limited range of local staple cereals. Horo and Topno (2015) identified 20 wild and semi-wild plants from 13 families and 19 genera that are rich in protein, calories, carbohydrates, potassium, iron, calcium, vitamin A, and vitamin C. This underscores the need for further documentation, nutritional analysis, and domestication of wild edible plants to help combat food insecurity and ensure dietary diversity (Lulekal et al., 2011). Wild edible and semi-wild plants have the potential to withstand climate variability and drought better than cereal crops, making them nutritionally valuable in challenging conditions.

Despite the important role of wild edible plants in supporting rural communities in Ethiopia, little attention has been given to the inventory and conservation of these species (Addis et al., 2005; Berihn and Molla, 2017). Many of these edible species face the risk of loss due to anthropogenic and environmental disturbances. Research on wild edible plants in Ethiopia has been limited and has only covered a small portion of the country (Molla et al., 2011). Various numerical taxonomic methods are available for classifying and understanding the patterns of phenotypic diversity and relationships between species (Gupta et al., 1991; Dias et al., 1993; Amurrio et al., 1995; Li et al., 1995). However, due to the scarcity of studies and available records, there is a need for in-depth research in this area.

Research and development in Ethiopia, particularly in Tigray, are generally underdeveloped. Many wild edible plants are threatened because traditional knowledge associated with them is at risk of being lost, leading to the depletion of these valuable resources through deforestation and other factors. Furthermore, research and development on wild plant phenotypic diversity, their nutritional contributions, and conservation approaches in Tigray remain insufficient. Ethiopia has a wealth of native wild plant species with significant commercial potential as food crops (Molla et al., 2011; Yohannes, 2016). In Ethiopia, where the majority of the population lives in rural areas, wild edible and semi-wild plants are valuable resources for supplementing staple foods, ensuring food security, promoting dietary diversification, and providing sustained income (Asfaw and Tadesse, 2001; Bahru et al., 2013; Kidane et al., 2014). However, despite their role in supporting rural communities, little attention has been given to the inventory and conservation of these species (Addis et al., 2005; Berihn and Molla, 2017). Many of these edible species are at risk of loss due to anthropogenic and environmental disturbances. Research on WEPs in Ethiopia has been limited and has covered only a small portion of the country, with particularly low attention given as Tigray, and is general low (Molla et al., 2011).

Materials and methods

Study area and agro-ecology

This study was conducted in the northern Eastern of Tigray Region, considering agro ecological and attitudinal variations. Study district representing woredas were Tahtay adiyabo, Tahtay koraro and Tselemti.

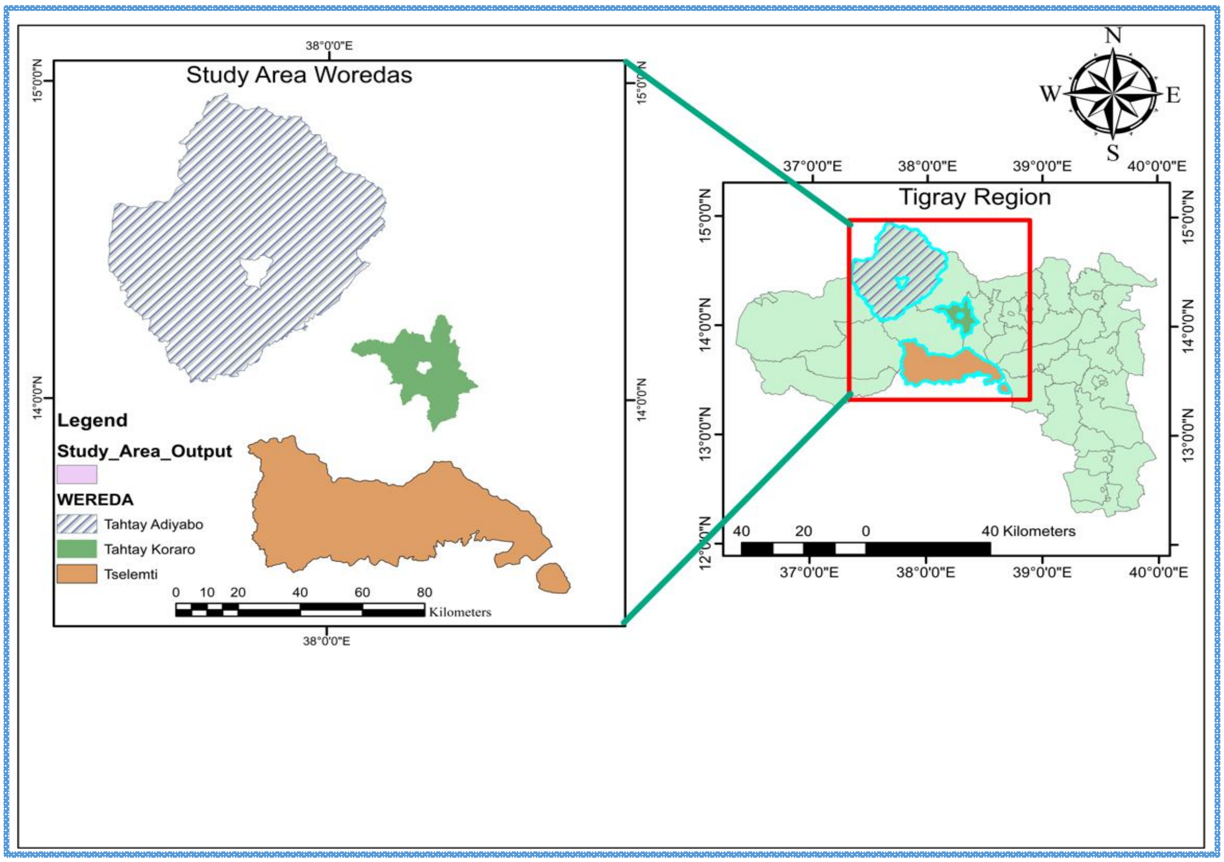

Figure 1 Study Woredas of Tigray Tselemti, Tahtay koraro and Tahtay Adiyabo

Socio-economic and climate characteristics of the study area

Over 90% of the population in the study areas heavily depend on rain-fed farming system and are extremely vulnerable to projected climate change which will potentially affect food production and food security of the people in the study areas. In general, annual crop, livestock, and forest products are the main sources of income for the farmers in study districts (Mohajan, 2013). The northern of Ethiopia are very susceptible to drought and drought related environmental and humanitarian crisis (Teshome and Zhang, 2019). Rainfall seasonality across the Northern study sites were unimodal, extends from June to September with maximum rain received from June to August (Mokria et al., 2017).

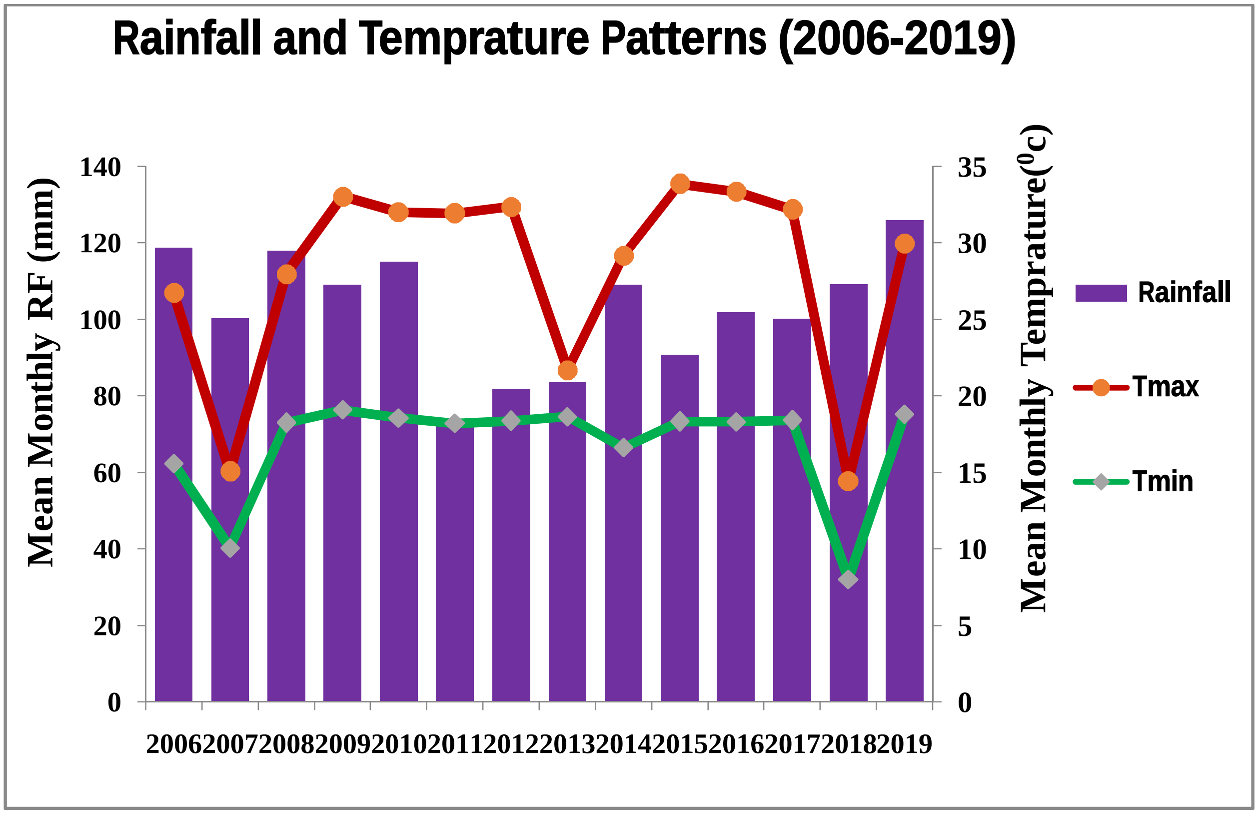

Figure 2 Climate characteristic of the study area

Study species, characteristics and distribution

For this study, we selected *Ximinia americana*,*Cordia africana*,*Ficus sycomorus* , *Adonosia digitata*, *Hyphae thebica*, *Tamarindus indica and Syzygium guineense* based on their geographical distribution across all the study site and wider uses as a source of income, food, nutrition and medicine by the community inhabited across the northern of Ethiopia (Feyssa et al., 2011; Lulekal et al., 2011). For extensive description of species distribution, characteristic, chemical and nutrient composition as well as their wider-scale uses across the region.

Fruit sample collection and processing

Fruit samples were collected from randomly selected ten individual trees per species from each study sites (Chen et al., 2019; Tewolde-berhan, 2014). Sample from the same species and site were accumulated in one bucket to form a composite sample (Nyanga et al., 2013; Tewolde-berhan, 2014) The composite samples were washed with tap water, then laid on plastic flat sheet on the floor of clean house and left for a week for air drying at room temperature (Nyanga et al., 2013; Tewolde-berhan, 2014). All species-specific fruit samples were cut into slices and separately spread on plastic flat-bottomed bowls for drying under room temperature. Finally, dried species-specific composite fruit samples were ground to fine powder in a mixer grinder and sieved through mesh and used for proximate and mineral analysis.

Proximate composition and mineral analysis

Dried and homogenised powdered fruit samples were analyzed for dry moisture, crude ash, crude fibre, crude fat, and crude protein according to the AOAC (1990) official methods (AOAC, 1990; Murthy et al., 2019). The crude protein was computed using AOAC 920.152 – method from the sample percentage of nitrogen content as determined by the Kjeldahl procedure multiplied by a factor (6.25) (Nyanga et al., 2013).

$$\%\,\textbf{Crude protein} = \%\textbf{N x 6.25} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \textbf{Eq. 1}$$

The crude fiber was calculated using AOAC 978.10 method from the loss in weight on the ignition of dried residue following the digestion of fat-free samples with 1.25% each of sulfuric acid and sodium hydroxide solutions. (Eq.2.). Crude fat was determined using AOAC 2003.05 method followed by extraction with a Soxhlet apparatus for 70 min using diethilic ether as the extraction solvent. the solvent was evaporated from the extraction flask (aluminum cup), then the amount of fat is calculated from the difference in weight of the aluminum cup before and after extraction (Silvanini et al., 2014).

$$\textbf{Crude fiber in \%} = \frac{(\textbf{W1} - \textbf{W2})\ \textbf{X100}}{\textbf{W3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \textbf{Eq. 2}$$

Where: W1- Crucible weight before drying, W2- Crucible weight after drying, W3- Sample dry weight

Moisture content was determined by drying the fruits at 92°C in an oven until a constant weight was obtained (Method: AOAC 930.04, AOAC 2005).

$$\textbf{Moisture content}\ (\%) = \frac{(\mathbf{W1} - \mathbf{W2})\mathbf{X100}}{\mathbf{SW}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{Eq.\,3}$$

Where: W_1: the weight of cap and fresh sample, W_2: the weight of dry sample and cap, SW: sample weight.

Furnace method (AOAC 940.26) was applied to determined Ash content, by burning in a muffle furnace at a temperature of 550°C for l hours. Iron (Fe), Zinc (Zn), Copper (Cu), Calcium (Ca) and Potassium (K) were estimated using AOAC official methods AOAC 999. 10 and Atomic Absorption Spectroscopy (AAS). Total carbohydrate was obtained by calculating the difference (Carbohydrate % = 100 – (% moisture + % crude protein + % crude fat + % ash+%crude fiber). Potassium content was estimated by Flame photometer. The nutritive value or energy content was estimated by multiplying the percentages of crudeprotein, crude fat and total carbohydrates by 4, 9 and 4 respectively. Then, the values were converted to kilo calories per 100 gm of the sample (Kassegn, 2016).

Statistical Analysis

A descriptive analysis for each species were conducted to compare to the nutritional values of the species. We also compared our findings with previous studies done on the same species in other countries of Africa. Based on literature, values were also compared to other indigenous species of importance, and popular exotic fruit providing tree species. The mean significance difference of the nutritional composition among WEP across sites were analyzed using one-way analysis of variance (ANOVA). The significance of differences between WEPs in mean proximate and mineral composition were tested using the least significant difference test (LSD) with $P < 0.05$. Pearson correlation analyses were conducted to test the relationship between proximate and mineral compositions in each species.

3. Results

3.1. Macronutrient contents

The amount of crude protein, crude fiber, crude fat, ash, moisture content, carbohydrate and the nutritive value was significantly varied among the wild and semi-wild edible fruits (Table 1). The highest percentage value of the fiber, fat and moisture content was recorded in *T. indica*fruits, nutritive value and carbohydrate in *C.africana*fruits whereas the crude protein and ash content was found to be higher in *S.guineense* and *C.africana*with 8.04 % and 5.09 % respectively (Table 1)

Table 1: Mean macronutrient composition of the wild and semi-wild edible fruits

Macronutrients	Tree species							*P*-value
	T.indica	*X.americana*	*H.thebica*	*F.sycomorus*	*C.africana*	*S.guineense*	*A.digitata*	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Crude protein (%)	3.32 ± 1[a]	8.04± 1.1[b]	2.44± 1.7[b]	4.63± 1[a]	5.09± 0.9[c]	4.53 ± 2.1[d]	2.02 ± 0.8[c]	0.000
Crude fiber (%)	9.62 ± 0.4[a]	7.48± 0.9[b]	16.69± 1.9[c]	23.27± 2.9[d]	6.8 ± 1[b]	11.4 ± 3[e]	26.3 ± 3.5[d]	0.000
Crude fat (%)	0.92± 0.3[a]	3.63± 0.6[b]	2.59± 0.2[a]	3.85± 2[c]	0.47± 0.4[d]	2.14± 0.3[a]	0.25± 0.5[e]	0.000
Moisture (%)	15.63± 2[a]	14.25± 1.9[abc]	8.20± 3[b]	11.73± 2[ab]	13.48± 5.5[d]	16.48± 2.0[bc]	12.86± 5[e]	0.000
Ash (%)	7.72 ± 1[a]	8.49± 0.8[a]	6.77± 0.7[b]	9.89± 0.7[a]	12.46 ± 0.2[c]	12.46 ± 0.4[b]	4.53 ± 0.4[d]	0.000
Carbohydrate (%)	62.79± 5[a]	58.11± 5 [b]	63.31± 5[c]	46.65± 4.9[d]	59.28± 4.4[e]	55.05 ± 5.2[b]	71.76 ± 3.4[f]	0.000
Nutritive value (Kcal)	347.2 ± 8.4[a]	241.7 ± 5.4[bf]	264.2 ± 6.1[c]	240 ± 5.4[d]	283.4 ± 6.6[e]	258.4 ± 9.8[f]	160.6 ± 9.6[g]	0.000

Means in a row with similar letters are not significantly different at $P<0.05$.

3.2. Mineral composition

The iron, zinc, calcium, copper, potassium and phosphorus of the indigenous and adopted food trees are depicted in Table 2. *F.sycomorus*fruits contained a higher content of iron, zinc, calcium and copper content. Available potassium was recorded lowest in *C.africana*and highest in *T.indica* among all the studied fruits while the available phosphorus was higher in *X.americana* and*S.guineense* correspondingly.

Table 2**:** Mineral composition of the wild and semi-wild edible fruits

Macronutrients	Tree species							*P*-value
	T.indica	*X.americana*	*H.thebica*	*F.sycomorus*	*C.africana*	*S.guineense*	*A.digitata*	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Fe (mg/100g)	13.8 ± 1.7[a]	8.5 ± 2[b]	4.2 ± 0.9[c]	56.5 ± 5[d]	6.0 ± 2[e]	10.6 ± 2.4[f]	14.4 ±2.9[a]	0.000
Zn (mg/100g)	0.5 ± 0.1[a]	0.9 ± 0.1[b]	0.4 ± 0.1[a]	1.6 ± 0.2[d]	0.32 ± 0.1[a]	1.3 ± 0.2[e]	1.5 ± 0.4[de]	0.000
Ca (mg/100g)	255.6 ± 5[a]	402.9 ± 12[b]	204.9 ± 9[c]	584.3 ±14[d]	362.2 ± 8.3[e]	515.1 ± 7[f]	481.8 ± 21.7[g]	0.000
Cu (mg/100g)	0.5 ± 0.0[a]	0.5 ± 0.1[a]	0.6 ± 0.1[a]	0.9 ± 0.1[b]	0.1 ± 0.0[c]	0.6 ± 0.2[a]	0.5 ± 0.1[a]	0.000
K (mg/100g)	3030.3 ± 0.3[a]	2704 ± 8[b]	2002.9 ± 2[c]	1477.1 ± 6[d]	760.5 ± 9[e]	1597.7 ± 3[f]	1127.8 ± 8.1[g]	0.000
P (mg/100g)	30.9 ± 5.0[a]	106.7 ±11[b]	85.8 ± 10.9[c]	83.3 ± 13.2[c]	26.1 ± 2.1[a]	105 ± 7.2[b]	40.4 ± 4.8[d]	0.000

Means in a row with similar letters are not significantly different at *P*<0.

4. Discussion

4.1. Macronutrient contents

The protein content of the fruits, as depicted in Table 1, ranged from 2.02 ± 0.8% for *Adansonia digitata* to 8.04 ± 1.1% for *Ximenia americana*. The protein content of the studied fruits was higher than the reported values for other wild edible fruits. For example, *Balanites aegyptiaca* (1.40%), *Ziziphus spina-christi* (2.13%), and *Grewia flavescens* (1.51%) in other semi-arid regions of eastern Ethiopia (Feyssa et al., 2011). Similarly, *Cordia africana*, *Ficus sycomorus*, *Hyphaene thebaica*, *Tamarindus indica*, and *Syzygium guineense* were found to be abundant in crude protein compared to the findings of Ahmed and Sati (2018), who reported 4.1% protein for *Z. spina-christi* and 3.95% for *Z. abyssinica* in Sudan.

Crude fiber content was highest in *A. digitata* (26.3 ± 3.5%), followed by *F. sycomorus* (23.27 ± 2.9%), *H. thebaica* (16.69 ± 1.9%), *S. guineense* (11.4 ± 3.0%), *T. indica* (9.62 ± 0.4%), *X. americana* (7.48 ± 0.9%), and *C. africana* (6.8 ± 1.0%). Except for *C. africana*, all the wild fruits contained higher crude fiber than reported by Feyssa et al. (2011) for *B. aegyptiaca* (5.94%), *Z. spina-christi* (3.78%), and *G. flavescens* (6.68%). Additionally, Adekunle and Adenike (2012) found 6.09 ± 0.02% crude fiber in *Z. spina-christi* fruits.

Crude fat content varied significantly among the studied fruits, with the highest value found in *F. sycomorus* (3.85 ± 2%) and the lowest in *A. digitata* (0.25 ± 0.5%). The crude fat content for all of the studied species was higher compared to the findings of Ahmed and Sati (2018), who reported 0.9%, 0.8%, and 0.3% for *Z. spina-christi*, *Z. abyssinica*, and *Z. mauritiana*, respectively. Moisture content ranged from 8.20 ± 3% to 16.48 ± 2.0%, with the highest and lowest moisture content observed in *H. thebaica* and *F. sycomorus*, respectively. Compared with other studies on *B. aegyptiaca*, *G. flavescens*, and *Z. spina-christi* fruits (Feyssa et al., 2011), the moisture content of the studied fruits was lower, indicating that these wild and semi-wild edible fruits are rich in energy and less susceptible to deterioration.

Syzygium guineense (12.46 ± 0.4%) had the highest ash content, while *A. digitata* (4.53 ± 0.4%) had the lowest. The ash content of the studied fruits was relatively lower than that reported for *B. aegyptiaca*, *Z. spina-christi*, *G. flavescens* (Feyssa et al., 2011), and *Carissa carandas* L., *Phyllanthus emblica* L., and *Morinda pubescens*(Anand and Deborah, 2016). The total carbohydrate content was 71.76 ± 3.4%, 63.31 ± 5%, 62.79 ± 5%, 59.28 ± 4.4%, 58.11 ± 5%, 55.05 ± 5.2%, and 46.65 ± 4.9% for *A. digitata*, *H. thebaica*, *T. indica*, *C. africana*, *X. americana*, *S. guineense*, and *F. sycomorus*, respectively. The total carbohydrate content of the studied fruits was lower than the values reported by Feyssa et al. (2011), who found 86.83%, 82.04%, and 89.46% for *B. aegyptiaca*, *Z. spina-christi*, and *G. flavescens*, respectively. The energy values were highest in *T. indica* (347.2 ± 8.4 kcal), followed by *C. africana* (283.4 ± 6.6 kcal), and lowest in *A. digitata* (160.6 ± 9.6 kcal). This calculated nutritive value, based on crude protein, crude fat, and total carbohydrate, is relatively lower than the values reported by Feyssa et al. (2011).

4.2. Mineral composition

Ficus sycomorus fruit contained the highest levels of iron (56.5 ± 5 mg/100g), zinc (1.6 ± 0.2 mg/100g), calcium (584.3 ± 14 mg/100g), and copper (0.9 ± 0.1 mg/100g) compared to *Cordia africana*, *Hyphaene thebaica*, *Tamarindus indica*, and *Syzygium guineense* fruits. The concentrations of zinc and copper in all the studied fruits were similar to the reported values for other wild edible fruits, such as *Arbutus pavarii*, *Nitraria retusa*, and *Ficus palmata* (Hegazy et al., 2013). However, the calcium and iron contents in the studied fruits were higher than those found in the fruits reported by Hegazy et al. (2013). Available potassium was significantly lower in *C. africana* (760.5 ± 9 mg/100g) and higher in *T. indica* (3030.3 ± 0.3 mg/100g) among all the studied tree species. According to the WHO (2012) Dietary Reference Intakes (DRI), the recommended potassium intake for adults is at least 3,510 mg/day, and for children, it is less than 3,510 mg/day. The potassium content in all the wild and semi-wild edible fruits studied requires additional supplementary foods to meet the daily potassium intake for adults, but it is sufficient for children. The available phosphorus in the wild and semi-wild edible fruits was 30.9 ± 5.0, 106.7 ± 11, 85.8 ± 10.9, 83.3 ± 13.2, 26.1 ± 2.1, 105 ± 7.2, and 40.4 ± 4.8 mg/100g in *T. indica*, *X. americana*, *H. thebaica*, *F. sycomorus*, *C. africana*, *S. guineense*, and *A. digitata*, respectively.

5. Conclusion

Ximenia americana, *Cordia africana*, and *Ficus sycomorus* have higher crude protein content, while *Adansonia digitata*, *F. sycomorus*, and *Hyphaene thebaica* have higher crude fiber content. Lower fat and ash contents were observed in *A. digitata*, *C. africana*, *Tamarindus indica*, *Syzygium guineense*, and *H. thebaica*, and the highest fat and ash contents were recorded in *X. americana* and *F. sycomorus*, respectively. *S. guineense*, *T. indica*, *X. americana*, and *C. africana* fruits have higher moisture content. Additionally, higher energy values and total carbohydrate contents were found in *A. digitata*, *H. thebaica*, *T. indica*, *S. guineense*, *C. africana*, *X. americana*, and *F. sycomorus* fruits. The highest levels of iron, zinc, calcium, and copper were observed in *F. sycomorus* compared to the other fruits. The fruits of *T. indica* and *S. guineense* have higher potassium content, while *X. americana* and *F. sycomorus* contained the highest amounts of phosphorus. Overall, the results indicate that wild and semi-wild edible fruits contain promising amounts of macronutrients and minerals, which have the potential to address nutrient deficiency issues.

Declarations and verification

The research work has not been published previously or it is not under consideration for publication elsewhere.

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