Identification and Analysis of Nutritional Components of *Enset* (*Ensete ventricosum*) Landraces Suitable for Corm Production in Southern Ethiopia

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Abstract

Enset (Ensete ventricosum) produces a nutritious human food from its vigorous pseudostem, corm and the stalk of inflorescence. Among the many different food made from Enset is 'Amicho', which is a stripped corm of a younger plant of Enset, boiled and consumed in a way similar to Irish potato, sweet potato and cassava. Participatory Rural Appraisal (PRA) and formal survey were conducted in two weredas, one from each of two densely populated Enset growing zones (namely Sidama and Hadiya zones in the Southern Nations, Nationalities and Peoples Region of Ethiopia) to collect Enset landraces suitable for edible corm production and assess their nutrient contents. Eleven Enset landraces suitable for edible corm production were identified and planted at Hawassa University experimental field for further investigation. The result of nutritional analysis showed a marked significant variability in the nutritional composition of the corms; this made the selection of nutritionally-rich Enset landraces possible. Large differences in protein content (0.90 to 2.39%), crude fibre (0.83 to 1.1%), carbohydrates (27.3 to 39.4), Fe (1.1 to 4.3 mg/100 gm), Zn (6.2 to 15.6 mg/100 gm) and Beta carotene (1.5 to 22.2 µg/100 gm) were recorded. 'Agade', 'Askala', and 'Gossalo' landraces had the highest protein, carbohydrates and Beta-carotene contents, respectively. 'Made' contained the highest crude fibre, Fe and Zn contents. The average protein content (1.4%) of corms of the Enset landraces was comparable to the average protein content of most root and tuber crops; whereas, the average Fe and Zn contents of corms of the Enset landraces were higher than the values reported for most root and tuber crops. The average energy and dry matter production rates of corms of the Enset landraces were about 124% and 169% higher, respectively than the average values for root and tuber crops. While Enset is conventionally perceived as having relatively low nutritional content when compared with other root and tuber crops, the present study provides evidence that, contrary to popular perception, there are excelling nutritional values of corms of the Enset landraces for humans.

Keywords: *Ensete ventricosum, landraces, corm, nutritional quality*

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Introduction

Enset (Ensete ventricosum (Welw.) Cheesman) belonging to the Family Musaceae) is a large perennial monocot banana-like plant that grows 4–8 m (sometimes even up to 12 m) in height. *Enset* traditionally ranked first in importance as a cultivated staple food crop for about 7–10 million people in the highlands of south and south-western Ethiopia and its use is expanding to other parts of the country.

Enset is cultivated mainly as a Source of nutritional human food, and in fact almost every part of the plant is useful for various other purposes. Starch produced in the pseudostem, corm and the stalk of the inflorescence of *Enset* is scrapped and usually fermented, yielding to a food product locally known as '*Kocho*'. Another foodstuff from *Enset* is '*Amicho*', which is a stripped corm of a younger plant of *Enset*, which is boiled and consumed in a way similar to Irish potato, sweet potato and cassava. When there is a shortage of food, a young *Enset* plant can be uprooted before maturity and the corm can be cooked for immediate consumption. The corms of some landraces are also used to treat certain infectious diseases**.**

The perennial crop is used as a Source of staple food for humans in many areas of Southern Nations, Nationalities and Peoples' Region and some parts of Oromia. These areas are characterised by high density of human population (Quinlan, *et al*. 2014), which is much higher than both the national average and the regional average for SNNPR (CSA 2008). Stanley (1966), Pijls *et al*. (1995) and Tsegaye and Struik (2001) indicate that the yield of *Enset* is relatively higher compared with other food crops. In addition to the higher yield both in terms of weight and energy, *Enset* can survive in areas with prolonged dry seasons (Mohammed *et al*. 2013; Kumo 2014). Lack of rainfall can only retard the growth but cannot kill the plant due to the accumulated moisture in its pseudostem. As a result, famine rarely occurs in areas where *Enset* is widely grown.

In addition, *Enset* has important ecological functions such as producing organic matter, creating a nutrient reservoir in the soil and controlling erosion, thus contributing to the stability and continuity of farming (Tesfaye 1996). Recently, there has been a marked increase in awareness of the importance of *Enset* for food security and environmental sustainability. As a result, many governmental and non-governmental organisations have started to introduce this crop to other parts of the country where it was not traditionally cultivated. The acceptability of this crop by new cultivators and consumers could, however, be challenged by the tedious and cumbersome harvesting and processing procedures and the sour taste of its fermented product, '*Kocho*'. Moreover, the perception of the people about the nutritional composition of *Enset* in general and *Enset* corm in particular, might hinder the expansion of the crop to other areas.

Therefore, to minimise this challenge before overcoming the knowledge gaps in harvesting and processing of *Enset* products, it is important for communities in traditionally non-*Enset* growing areas to get used to the sour taste of '*Kocho*". In addition, the promotion of landraces with high quality '*Amicho*' in to cultivation may facilitate the adoption of *Enset* into non-*Enset*-growing areas as '*Amicho*' neither has the sour taste that people experience with '*Kocho*' nor does it require special skills for preparation.

Despite the importance and roles of *Enset* for attaining food security and environmental sustainability and the favourable considerations of governmental and non-governmental organisations to introduce *Enset* to areas that are not traditionally *Enset* growing, very little attention is given to identification of landraces fit for different uses as well as to conducting a systematic studies on the specific uses of *Enset* landraces, their pattern of growth and development and the indigenous knowledge and the assessment of the nutritional value of corms of landraces suitable for *Amicho* production. The very fewstudies so far published on the nutrient composition of *Enset* are restricted to '*Kocho*' or other food items (Buzuneh and Feleke 1966; Besrat *et al*. 1979; Pijls *et al*. 1995). With the researcher's cognisance of the gap of scientific evidence focusing on *Amicho*, landraces suitable for *Amicho* production, and their nutritional contents, this research aimed to: (1) identify *Enset* landraces suitable for corm production in the different *Enset* growing areas; (2) study the growth, development and productivity of *Enset* landraces suitable for corm production; and (3) analyse the nutritional contents of the identified landraces.

Materials and Methods

The Study Sites

The study was conducted in two densely populated *Enset* growing zones, namely Sidama and Hadiya zones in the Southern Nations Nationalities and Peoples region (SNNPR) of Ethiopia. Hagereselam (2600–2650 masl) and Anna-lemmo (2220–2400 masl) woredas were selected from Sidama and Hadiya zones, respectively.

Materials Used

1. Suckers of the 11 *Enset* landraces that were identified as suitable for corm production;
2. Scrapper for scrapping the suckers to facilitate easy sprouting of new *Enset* plants from the buds;
3. Shade under which the wounded suckers were made to heal from their wounds;
4. Experimental seedling bed for transplanting of *Enset* suckers.
5. Measuring tape with grids for measuring sucker and leaf height as well as psedostem circumference;
6. polyethylene bags and transported in an ice box to the Ethiopian Health and Nutrition Research Institute Laboratory
7. Pan and water for washing corms of the landraces,
8. Matchet for cutting corms of the landraces into small pieces,
9. The crude fat content was determined using diethyl ether in a Soxhlet extraction apparatus, and the crude fibre content by dilute acid and alkali hydrolysi
10. diethyl ether in a Soxhlet extraction apparatus for determining the crude fat content
11. dilute acid and alkali hydrolysi for determining the crude fibre content
12. 15 ml of concentrated nitric acid (HNO_3) and 2.0 ml of 70% perchloric acid ($HClO_4$) for refluxing dried and powdered samples
13. an automated atomic absorption spectrophotometer (PyeUnicam Model SP 191, Cambridge) for determining the mineral content of each sample;
14. solutions of known concentration against which the mineral contents of the samples were quantified

Methods

Participatory Rural Appraisal (PRA) and group discussions were carried out with farmers. In the two-*Enset* growing study areas, a group of male and female key informants were asked to name *Enset* landraces. The farmers identified the names of *Enset* landraces suitable for *Amicho* production and their specific uses and characteristics. This information was used to develop and pre-test a formal survey questionnaire, which was administered to 50 households in each of the two study sites. For each household, the survey recorded the number of *Enset* landraces, the vernacular names of each landrace and its specific uses. In the process, 11 *Enset* landraces were reported to be suitable for corm production. These landraces were collected and planted at the Research Farm Centre of Hawassa College of Agriculture.

Field Experiment

Field experiment was carried out at HHawassa University. The site is located at 7° 04' N, 38°31'E with an altitude of 1650 masl. The soil characteristics (0 to 30cm soil depth) is 54% sand, 27% clay silt and 19% clay with pH ranging from 5.36 to 6.31 (Tsegaye and Struik 2002). According to the Hawassa Meteorological Centre report, the annual average rainfall for the years 2008–2011 was 826.4mm with a minimum mean air temperature of 11.6°C and a maximum of 28.2°C.

Suckers of the eleven landraces that were reported to be suitable for corm production were brought from Sidama zone (Hagresealm woreda) and Hadiya zone (Anna Lemo woreda) and planted at the Research Farm Centre of the Hawassa College of Agriculture. After three years, the eleven landraces were uprooted and the central parts of the corms were scrapped until the growing bud was removed in order to produce uniform suckers for field experiment. The corms were placed in shade for 2–3 days in order to allow the wounds to heal. They were then planted within a space of one square meter each. Suckers appeared after 2–3 months and were left to grow undisturbed for one year. The suckers of the eleven landraces that remained in the nursery for one year were transplanted to a new experimental area of 1584 m^2 on 7 September 2008. The eleven landraces (treatments) were arranged in randomised complete block design with three replications. The suckers of each landrace were grown in a plot in 1.5m x 2.0m plant arrangements. There were 16 suckers per plot of 8m x 6m. The total numbers of suckers planted were 528. Healthy and vigorous suckers were selected to be used for the field experiment.

Data Collection on Growth Parameters

After transplanting, the *Enset* suckers had slow growth rate due to shortage of rainfall. Thus, data collection was delayed until the suckers reached measurable height and circumference of pseudostem. On 7 December 2010 and afterwards at 3 months intervals data on Leaf Area Index (LAI), pseudostem circumference, pseudostem height, plant height and leaf number were recorded. The final harvesting of edible corms was conducted on 7 September 2011, after three years of transplanting of *Enset* suckers.

Mean Leaf Area

Leaf areas (L_a in m^2) were assessed by measuring the length and width of individual leaves and calculating the area using the formula developed for banana by Turner (1972), that is:

$$La = \Sigma\ (0.83 \times l \times b)/P_n$$

where, l is the length of lamina (m), b the maximum width of lamina (m) and P_n the number of leaves per plant.

LAI = LAI (m^2 m^{-2}) was estimated as a product of number of plants per unit ground area (p_g), number of leaves (P_n) and the mean area of a single leaf (L_a) (Tsegaye and Struik 2002)

$LAI = P_g \times P_n \times L_a$

Plant height (in m) was measured in two plants from the ground to the petiole of the last emerging leaf. Pseudostem circumference was measured 20cm above corm and did not include pruned or partial leaf sheaths. Pseudostem height was measured from the corm junction to the cut-off point indicated by the women who participated in the study.

General Sample Preparation

The 11 landraces of *Enset* that were planted on the experimental field on 7 September 2008 were harvested on 7 September 2011. From each cultivar and plot, three *Enset* plants were randomly uprooted. The pseudostems were cut just at the junction of the pseudostems and corms. The outer surfaces of the corms including the roots were scraped to remove all inedible parts of the corm. The corms of the landraces were then washed, cut into small pieces, mixed and dried in the open air to remove external moisture. The cut corms were then placed in polyethylene bags and transported in an ice box to the Ethiopian Health and Nutrition Research Institute Laboratory (EHNRI) in Addis Ababa within 24 hours after harvesting. In the EHNRI laboratory, the samples were kept at -20°C until they were analysed.

Proximate Analysis

Before the analysis, the sample corms were thawed for 5 hrs at room temperature and milled in a food processor. The proximate composition of protein, crude fibre, crude fat, ash and moisture content of the edible portions of five duplicate corm samples were determined according to the methods of Association of Official Analytical Chemists (Helrich 1990). The moisture content was determined from 10g samples of shredded materials by drying them to constant weight at 92^{o}C**.**The crude protein content was determined by micro-Kjeldahla methods (% protein = %N x 6.25). The crude fat content was determined using diethyl ether in a Soxhlet extraction apparatus, and the crude fibre content by dilute acid and alkali hydrolysis. The carbohydrate content was estimated by difference. The energy value was calculated using water factors (values for crude protein, fat and carbohydrates were multiplied by 4, 9 and 4, respectively, and results summed)

Determination of Minerals

Duplicate aliquots (500 mg) from each of the dried and powdered samples were weighted, and then wet-ashed by refluxing overnight at 150^{o}C with 15 ml of concentrated nitric acid (HNO_3) and 2.0 ml of 70% perchloric acid ($HClO_4$). The samples were dried at 120^{o}C and the residue was dissolved in 10 ml of 4.0 N HNO_3–1% $HClO_4$. The mineral content of each sample was determined by means of an automated atomic absorption spectrophotometer (PyeUnicam Model SP 191, Cambridge), as outlined in AOAC (Helrich 1990), for the specific minerals Fe, Zn and Ca. The mineral contents of the samples were quantified against solutions of known concentration, which were analysed simultaneously.

Statistical Analysis

The yield data of the components of the *Enset* plant, specifically those of corm were processed by the analysis of variance procedure. Mean comparison was performed using Duncan's multiple range test to assess the effect of different cultural practices on the total yield of the crop.

Results and Discussion

The average number of leaves in the 11 landraces ranged from 3 to 5 at first counting date and from 4.6 to 6 at the last counting date, and significantly differed among the *Enset* landraces at all counting dates (Table 1). 'Gosollo', 'Kule', 'Derassa' and 'Ado' landraces recorded 29% higher than the lowest leaf number. The LAI of the *Enset* landraces ranged 0.74–1.42 at first harvesting date, 0.98–1.87 at the second, 1.28–2.37 at the third and 1.52–2.95 at the fourth harvesting dates, respectively. Except at the second and fourth harvesting dates, there was no significant difference in LAI among the *Enset* landraces. However, 'Kule' recorded the highest LAI at all harvesting dates. The average leaf number values found in this study are lower than the average leaf number values of 11.57, reported by Endale (1997) for *Enset* landraces suitable for '*Kocho*' production. This means that *Enset* landraces suitable for corm production produce lesser number of leaves compared with *Enset* landraces suitable for '*Kocho*' production. There was no significant difference in circumference of pseudostem among the landraces (Table 2). However, there was a significant difference in height of pseudostem among the landraces in all harvesting dates. Height of pseudostem ranged from 0.28 to 0.69 and 0.73 to 1.30 on the first and last harvesting dates, respectively. On the last harvesting date, Shewite and Hayiona scored the highest and lowest pseudostem height, respectively. The average base circumference and height of pseudostemwas lower than the mean circumference (1.24 m) and mean height of pseudostem (1.69), as reported by Endale (1997), indicating that *Enset* landraces suitable for corm production have less vigorous pseudostem.

The protein content of corms was highly variable. On the basis of protein content (Table 3), *Enset* landraces that were studied can be divided into three groups**:** high protein (2.396%, 'Agade'), intermediate protein (1.063–1.927%, 'Made', 'Shewite', 'Kiticho', 'Derasa-ado', 'Zobera', 'Hayiwona' and Gimbo') and low protein (0.900–0.936%, 'Kule, Askala and Gossalo') landraces. The protein content of 'Agade' (2.396 %) is higher than values reported for potato (1.8 % documented by Hiebsch and O'Hair 1986), sweet potato (1.28–2.13% reported by Ishida *et al*. 2000 and 2.1% by Alkubor 1997) and cassava (0.95–6.42% reported by Ceballos *et al*. 2006) but lower than the protein content of yam (3.1–8.9% reported by Agor-Egbe and Treche 1995). The average protein content of corms of *Enset* landraces (1.412 %) was comparable with the average protein content of most root and tuber crops; but it was lower than the protein content of cereals (Hiebsch and O'Hair 1986) and *Kocho* (Nurfeta, Tsegaye, and Abebe 2012). As *Kocho* is made from decorticated corms and scrapped sheaths of psuedostem of many *Enset* landraces, the difference in protein content between *Enset* corms and *Kocho* might be due to the variation in landraces. The landrace with high protein content was collected from Hadyia whereas the three landraces with low protein content were gathered from Sidama area. This is related to the difference in food culture of the communities in the two areas. During the survey work, it was observed that use of corm for food was more common in Hadiya than in Sidama. As a result, the Hadiya farmers might prefer high quality corm production more than the Sidama farmers do.

The protein content of *Enset* corms is not only important for human nutrition and animal feed. As *Enset* corms are used for propagation of suckers for planting, the protein content of corms enables the plant to survive periods of adverse conditions between growing seasons, and may provide nutrients to support the growth of new plants as seedlings from the corm. They act as a sink for nitrogen (and probably also sulphur), accumulating in greater amounts under conditions of excess nutrient supply, and they are also located in the cell in discrete deposit (protein bodies) which facilitate high level accumulation without any diverse effect on other cellular functions (Shewry2003). In this study significant differences in protein content (ranging from 0.900% to 2.396%) were observed, suggesting that considerable proportions of these differences are genetic**,** and therefore, there are ample possibilities for exploring them so as to conduct further study. The amino acid contents of *Enset* landraces also require further investigation.

The Beta-carotene contents in dry matter bases varied from 35.70 µg/100g in 'Gossalo to 1.473 and 1.700 µg/100g in 'Kiticho' and 'Hayiwona', respectively. Based on Beta-carotene contents of corms of *Enset***,** landraces can be divided into two groups: low (1.4–1.7 mg/100gm, 'Kiticho and Hyiwona') and intermediate (6.37–17.00 mg/100gm, 'Askala', ;Shewite', 'Zobra', 'Made', 'Kule', 'Derassa-ado' and 'Gissalo'). The Beta-carotene contents of 'Gossalo' and 'Derassaado' were 202%and 88% higher than the average content Beta-carotene of all landraces, respectively. However, the Beta-carotene contents of *Enset* corms were lower than the values reported for fresh carrot (323.5 mg/100 g) (Mdziniso *et al*. 2006) and fresh sweet potatoes (2606 ug/100 g) (Nunn *et al*. 2006).

The iron (Fe) content of the landraces varied from 1.10 to 4.33 mg/100gm. Based on the Fe content, the *Enset* landraces can be divided into three groups: high (4.33, 'Made' and ;'Gimbo'); 'intermediate (2.11–2.50, 'Gossalo', 'Agade', 'Kiticho', 'Shewite'); and low ('Askala', 'Haywona', 'Derassaado', 'Zobra' and 'Kule'). The Fe contents of corms of 'Made' and 'Gimbo' were significantly higher than those of 'Askala', 'Derassaado', 'Zobra', 'Hayiwona' and 'Kule'. Most of the *Enset* landraces were found to have higher Fe content than the values reported for cassava (1.16 mg/100g (Adewusi *et al.* 1999); sweet potato (1.9 mg/100g (by Ishida *et al*. 2000)and 0.7 mg/100g (by Umeta *et al*. 2005), Yam and Taro (0.4 and 0.7 mg/100g, respectively, (Umeta, West, and Fufa 2005). The iron content of 'Made' and 'Gimbo' is comparable with the average iron content of fermented wheat 'injera' (3.5mg/100g), maize porridge (3.6 mg/100g) and boiled maize and sorghum (3.65 mg/100g), as reported by Umeta *et al*. (2005). Diets in Ethiopia are based, to a large extent, on cereals and root and tuber crops. In areas where teff is the main staple food crop, prevalence of anaemia is relatively low as teff food is rich in iron. In *Enset*-growing areas, too, as *Enset* corms are rich in Fe, the prevalence of animea is presumed to be relatively low. However, this requires further investigation.

Based on the Zn content, the *Enset* landraces can be divided into two groups: High (10.15–17.82 mg/100g, 'Hayiwona', 'Derasaado', 'Gimbo', 'Kule' and 'Made') and intermediate (6.16–9.043 mg/100g, 'Shewite', 'Gossalo', 'Agade', 'Askala', 'Kiticho' and 'Zobra'). The Zn content of *Enset* corms was found higher than the values reported for cassava (13.1 ppm, Oboh and Akindahunsi 2003), yam (1.52 mg/100 g, Bhandari and Kawabata 2004, 0.58 mg/100 g and Umeta *et al*. 2005) and sweet potato (0.30 mg/100 mg, Umeta *et* *al*. 2005). In developing countries, zinc and iron are two of the micronutrients that are most often deficient in children and women of reproductive age, especially at risk of such deficiencies (Gibson 1994). Zinc deficiency has been shown to lead to poor growth (Umeta *et al*. 2000), impaired immunity, and increased morbidity from common infectious diseases (Sazawel 1999) and increased mortality (Sazawal *et al*. 1989). *Enset* corms are very rich in Zn, and thus Zn deficiency may not be a serious problem among consumers of *Enset*-based foods. Gebremedhin, Enqueselassie, and Umeta (2011) also reported that pregnant women from *Enset*-staple diet category were better-off in their zinc status when compared with pregnant women from maize staple diet category. However, Zinc deficiency arises to a large extent from impaired bioavailability of dietary zinc, largely attributed to the high phytic acid content of diets (Gibsen 1994). Thus, further investigation is required to find out the effect of phytic acid on the bioavailability of Zn in *Enset* corms.

The crude fibre content of the 11 landraces ranged from 0.833 to 1.117%, respectively, with 'Made' having the highest and 'Hayiwona' the least content. The crude fibre content of 'Made' was 13.74% higher than the average value for all landraces. The crude fibre contents of *Enset* landraces are lower than the average value reported for most root and tuber crops, such as sweet potato (2.8%, Alkubor 1997; 2.8%, Ishida *et al*. 2000), yam and cassava (2.6%, Ade-Omowaye *et al*. 2003). The low level of crude fibre contents among the *Enset* landraces might make foods containing products of these landraces desirable in infant feeding because fibre contributes to dietary bulk and is not digested in human gastrointestinal tract.

The ash levels are similar in all landraces that are studied. The values are very low compared to the values often found in other root and tuber crops, such as yam (1%, Ade-Omowaye *et al.*, 2003), sweet potato (2.5%, Alkubor 1997), cassava (0.7–2.3, Adewusi *et al* 1999), potato (5.83%, Gahlawat and Sehgal 1998). Similar to the ash level, the fat contents of *Enset* landraces are not variable across landraces. The fat values of the corms were also found lower than the fat values reported for other root and tuber crops, such as yam (1.20%, Ade-Omowaye *et al*. 2003 and 0.1–0.9%, Agbor-Egbe and Treche 1995); cassava (1.60%, Ade-Omowaye *et al*. 2003), sweet potato (0.3 %, Alkubor 1997 and Hiebish and O' Hair 1986), and potato (1.0%, Gahlawat and Sehgal 1998) but comparable to the values reported for taro (0.1%, Hiebish and O' Hair 1986).

There was a significant difference among *Enset* landraces in carbohydrate composition. The highest composition (39.413%) was obtained in 'Askala' while 'Kule' and 'Made' were found containing the lowest (27.267%) and second lowest (27.84%) , respectively levels of carbohydrate composition. The carbohydrate composition of 'Askala' was 41.55% higher than the lowest carbohydrate record of 'Made'. The carbohydrate values of *Enset* corms are low compared to the values found in most root and tuber crops, such as yam and cassava (79.9%, Ade-Omowaye *et al*. 2003) and sweet potato (87.30%, Alkubor 1997). However, the total carbohydrate contents of 'Askala', 'Gimbo' and 'Kule' were higher than the total carbohydrate content of traditionally-fermented '*Kocho*'[1] reported by Yirga (2013).

The food energy content (kcal/100g) of *Enset* landraces ranged from 109.763to 159.253. 'Askala' contained 16.24% more food energy than the average value for all cultivars. The food energy content of ‘Kule’ and ‘Made’was extremely lower compared with that of other landraces. The energy production (kJ m^{-2}) and energy production rate (kJ m^{-2} d^{-1}) of corms of *Enset* landraces in Table 4 were calculated from the results of this study; whereas the energy production and the energy production rate of root and tuber crops were calculated using food composition table compiled by EHNRI (1995–1997) and Platt (1977). There was a difference in energy production rate among corms of *Enset* landraces. The highest production rate (54 kJ m^{-2} d^{-1}) was found in ‘Askala’ whereas ‘Derassa Ado’ had the lowest (31.27 kJ m^{-2} d^{-1}) production rate. The energy production rate of corms of *Enset* landraces was much higher (on average by 124%) compared with that of root and tuber crops.

Edible dry matter production of *Enset* corms varied from 3.5 g m^{-2} d^{-1} in ‘Agade’ to 2.3 g m^{-2} d^{-1} in‘Hayiwona’. Based on edible dry matter production rate of corm, *Enset* landraces can be divided into three groups: high (3.0 g m^{-2} d^{-1} – 3.5 g m^{-2} d^{-1}, ‘Zobra’, ‘Kitcho’, ‘Askala’ and ‘Agade’), intermediate (2.5 g m^{-2} d^{-1}– 2.9 g m^{-2} d^{-1}, ‘Kule’, ‘Gossalo’, ‘Shewite’ and ‘Gimbo’**;** andlow (2.0 g m^{-2} d^{-1} – 2.3 g m^{-2} d^{-1} , ‘Hayiwona’ and ‘Derassa Ado’). The edible dry matter production rate of Agade was 30% higher than the average corm production of the other *Enset* landraces. *Enset* corm produced much more edible dry matter per unit area and time compared with other root and tuber crops (Table 4). The energy production rate of edible dry matter corm of *Enset* landraces was about 169% higher than the average value for root and tuber crops.

Enset is a monocarpic perennial herb and it takes about four years to produce edible corm. In this experiment, the *Enset* landraces produced very large corm after three years. The *Enset* corm can be pulverised into smaller pieces to be mixed with the fleshy scrapped pseudostem. The mixture is then buried in a pit and left to ferment for a certain period of time, often thirty days**.** After about one month the product **is** ready for consumption.

Conclusions

The constant decrease in size of farmlands in Ethiopia resulting from continuous increase in the size of the population is becoming an incentive for farmers to grow *Enset* for food security and other uses. The productivity of *Enset*, which is much higher per unit area than that of other crops, its tolerance to drought and its multipurpose uses, including for ecological sustainability, makes it an ideal guarantee crop for food security in densely populated areas of Ethiopia and elsewhere. However, the population pressure has also posed a serious threat for many of the landraces. Better documentation of characteristics, specific uses and nutritional values of these landraces can serve to attract the attention and interest of policy makers, farmers and consumers toward supporting efforts to sustain and expand harvesting of the landraces. In these areas there are many *Enset* landraces suitable for corm production.

The results of this study showed that there exists a significant variability in nutritional composition which could be used to select nutritionally superior *Enset* landraces to be grown in the other major *Enset* growing areas and elsewhere. On the basis of high crude protein and starch level, the landrace 'Agade' could be selected. The average Fe and Zn contents of corms of *Enset* landraces are higher than the values reported for most root and tube crops, thusmaking *Enset* corms the best Source of the two most deficient micronutrients in developing countries.

While there are misconceptions about the nutrition status of *Enset* products; many researchers and policy makers believe that *Enset* food products are nutritionally inferior to the food products from other crops; the present study provides evidence of the potential nutritional values of the *Enset* plant for populations who depend on *Enset* as traditional staple food and for those in the areas where *Enset* is being newly introduced.

Acknowledgements

The author thanks J. William Fulbright Foreign Scholarship Board, Norwegian Agency for Development Cooperation (NORAD), Oklahoma State University and the Christensen Fund for providing funds and facilities. Thanks are also due to Mr. Asmamaw Zemene for assisting in the data collection.

Notes

1. *Kocho* is a mixture of decorticated corm and scrapped sheaths of pseudostem, which is buried in a pit to ferment for about 30 days. The fermentation process which includes breaking down of more complex compounds by enzymes might reduce the total carbohydrate content of '*Kocho*'.

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Table 1. Average leaf number and LAI of *Enset* landraces, at different weeks after transplanting into permanent field

Landraces	Weeks after transplanting							
	07/12/10		07/03/11		07/06/11		07/09/11	
	Number of leaves	LAI	Number of leaves	LAI	Number of leaves	LAI	Number of leaves	LAI
Agade (H)	4.0 b	0.96	4.66 bc	1.42 ab	5.66	1.80	5.67 a	2.04 b
Hayiona (H)	4.3 ab	0.74	4.67 bc	1.04 b	5.33	1.35	5.67 a	1.59 b
Zobra (H)	5.0 a	0.93	5.67 a	1.48 ab	5.67	1.64	5.67 a	1.74 b
Gimbo (H)	4.0 b	0.77	5.33 ab	1.61 ab	5.67	1.71	6.00 a	1.95 b
Kule (S)	3.7 bc	1.42	4.67 bc	1.87 a	5.33	2.37	6.00 a	2.95 a
Astra (S)	5.0 a	0.85	5.33 ab	1.29 ab	6.00	1.57	5.67 a	1.83 b
Derassaado (S)	5.0 a	0.89	4.67 bc	0.98 b	5.67	1.28	6.00 a	1.51 b
Gossilo (S)	4.3 ab	1.12	5.33 ab	1.52 ab	6.00	2.04	6.00 a	2.23 ab
Kiticho (S)	3.7 bc	0.91	4.67 cb	1.23 ab	5.67	1.95	5.67 a	1.99 b
Shewite (S)	3.0 c	0.76	4.33 c	1.29 ab	4.67	1.71	5.33 a	2.22 ab
Made (S)	3.7 bc	1.36	4.00 c	1.75 a	5.00	2.32	4.67 b	2.21 ab
Grand mean	4.15	0.98	4.85	1.41	5.55	1.77	5.67	2.02
CV (%)	9.18	33.00	9.49	24.27	6.76	22.15	7.58	23.74
Significance	***	Ns	**	*			*	*

*, **, and *** indicate significant levels at P < 0.10, 0.01 and 0.001 (f-test), respectively; ns = not significant. Different letters in a column indicate significance at P < 0.05, according to Duncan's Multiple range test'. Means followed by different letters are significantly different; (H) = Hadiya zone; (S)=Sidama zone

Table 2. Plant height, pseudostem height and circumference of *Enset* landraces at different weeks after transplanting into permanent field, and fresh and dry matter yield of *Enset* corms at final harvest

Landrace	Weeks after transplanting												Final corm yield	
	07/12/10			07/03/11			07/06/11			07/09/11			Fresh weight (kg/plant)	Dry weight (kg/plant)
	Plant height	Pse. Height	Pse Cir.	Plant height	Pse. height	Pse. Cir.	Plant height	Pse. height	Pse. Cir.	Plant height	Pse. height	Pse. Cir.		
Agade (H)	2.65 abcd	0.46 abc	0.99	3.16 abc	0.61 abc	1.09	3.53 abc	0.70 abc	1.08	3.06 b	0.94 abc	1.29	26.86	11.45
Hayiona (H)	1.75 d	0.28 c	0.76	2.48 c	0.41 c	0.91	3.03 bc	0.48 c	0.87	3.23 ab	0.70 c	1.13	20.83	7.71
Zobra (H)	1.92 cd	0.41 bc	1.19	2.83 bc	0.48 bc	1.25	3.18 abc	0.65 bc	1.21	3.22 ab	0.78 c	1.39	25.00	10.00
Gimbo (H)	1.77 d	0.44 bc	1.04	3.29 abc	0.51 bc	1.11	3.47 abc	0.62 bc	1.05	3.62 ab	0.83 c	1.33	24.83	9.68
Kule (S)	2.83 abc	0.60 ab	1.18	3.43 abc	0.73 ab	1.27	4.18 ab	0.78 ab	1.20	4.74 a	1.09 abc	1.40	27.17	8.15
Astra (S)	2.00 cd	0.32 c	1.07	2.73 bc	0.51 bc	1.12	2.99 c	0.57 bc	1.16	3.43 ab	0.77 c	1.43	26.67	11.24
Derassa-ado (S)	2.17 cbd	0.29 c	0.93	2.52 c	0.44 c	1.01	2.80 c	2.17 bc	1.01	3.07 b	0.73 c	1.17	18.33	6.60
Gossilo (S)	2.58 abcd	0.47 abc	1.19	3.24 abc	0.57 abc	1.18	3.76 abc	0.68 abc	1.17	3.69 ab	0.99 abc	1.34	24.33	9.00
Kiticho (S)	2.78 abc	0.43 bc	1.00	3.00 bc	0.56 abc	1.09	3.59 abc	0.71abc	1.04	4.00 ab	0.93 abc	1.20	28.67	10.6
Shewite (S)	2.95 ab	0.69 a	1.11	3,74 ab	0.79 a	1.24	4.34 a	0.91 a	1.18	4.62 ab	1.30 a	1.28	27.53	10.19
Made (S)	3.18 a	0.58 ab	1.02	4.08 a	0.78 a	1.09	4.28 a	0.96 a	1.10	4.65 a	1.19 ab	1.24	29.67	9.19
Grand mean	2.42	0.45	1.06	3.13	0.58	1.12	3.56	0.68	1.09	3.67	0.93	1.29	25.44	9.44
CV (%)	20.48	28.51	18.78	17.70	23.94	15.36	16.35	21.97	14.6	21.32	22.75	10.47	24.43	25.28
Significance	**	**	Ns	**	**	Ns	**	**	ns	**	*	ns	Ns	4.06

* and ** indicate significant levels at $P < 0.10$ and 0.05 (f-test), respectively; ns = not significant. Different letters in a column indicate significant at $P < 0.05$, according to Duncan's Multiple range test'.

Means followed by different letters are significantly different

(H) = Hadiya zone; (S)=Sidama zone.

Table 3.Chemical composition of *Enset* landraces suitable for *Amicho* production

Landraces	Moisture (%)	Fat (%)	Protein (%) (Nx6.25)	Crude fibre	Ash (%)	Carbohydrates (%) including fibre	Food energy Kcal/100 gm	Fe mg/100gm	Zn mg/100gm	Vitamin C mg/100gm	Beta-Carotene µg/100g
Agade (H)	62.75 bc	0.133	2.396 a	1.070 ab	1.310 c	33.413 b	140.160 ab	2.107 b	8.023 ab	1.700	7.883 bc
Hayiwona (H)	62.72 bc	0.113	1.773 abc	0.917 bc	1.533 abc	33.863 b	139.900 ab	1.463 b	10.150 ab	1.766	1.700 c
Zobra (H)	59.83 bc	0.127	1.667 abc	0.970 abc	1.327 bc	37.050 ab	152.127 ab	1.560 b	9.043 ab	1.833	9.267 bc
Gimbo (H)	61.18 bc	0.150	1.927ab	1.063 ab	1.420 abc	35.327ab	146.110 ab	4.300 a	10.497 ab	1.867	6.367 bc
Kule (S)	70.15 a	0.137	0.900 c	1.033 ab	1.550 abc	27.267c	109.763 c	1.870 b	15.553 ab	2.100	17.000 bc
Askala (S)	58.15 c	0.133	0.936 c	0.833 c	1.370 bc	39.410 a	159.253 a	1.110 b	8.060 ab	1.500	7.867 bc
Derasa Ado (S)	64.16 b	0.147	1.400 bc	1.056 ab	1.497 abc	32.790 b	133.853 b	1.480 b	10.153 ab	2.800	22.233 ab
Gossalo (S)	63.39 b	0.147	0.936 c	0.927 abc	1.383 abc	34.200 b	138.160 b	2.101 b	7.890 ab	2.333	35.700 a
Kitcho (S)	63.26 b	0.130	1.353 bc	0.923 bc	1.563ab	33.693 b	137.663 b	2.101 b	8.740 ab	1.967	1.473 c
Shewite (S)	63.45 b	0.180	1.186 bc	0.897 bc	1.433 abc	33.753 b	137.793 b	2.283 b	6.165 b	1.800	8.623 bc
Made (S)	69.34 a	0.127	1.063 bc	1.117 a	1.623a	27.840 c	112.287 c	4.33 a	17.82 a	0	11.933 bc
Mean	63	0.138	1.412	0.982	1.455	33.50	137.00	2.28	10.19	1.787	11.82
CV (%)	4.10	19.67	33.00	9.16	8.24	7.34	7.93	33.10	41.30		85.96
Significance	***	Ns	**	**	*	****	****	***	ns	ns	**

*, **, *** and **** indicate significant levels at P < 0.10, 0.05, 0.01 and 0.001 (f-test), respectively; ns = not significant. Different letters in a column indicate significant at P < 0.05, according to Duncan's Multiple range test' .
Different letters in a column indicate significant difference at P< 0.05, according to Duncan's multiple range test.
Means followed by different letters are significantly different.
(H) = Hadiya zone; (S)=Sidama zone.

Table 4. Average yield, edible dry matter production rates and energy production rates of root and tuber crops as compared with the corm yield, dry matter and energy production rates of different *Enset* landraces grown for corm production

Crops	Yield ($g\ m^{-2}$)	Dry matter yield ($g\ m^{-2}$)	Dry matter (%)	Growth period (days after transplanting)	Edible dry matter ($g\ m^{-2}\ d^{-1}$)	kJ/100 g of edible yield	Energy Production ($kJ\ m^{-2}$)	Energy production rate ($kJ\ m^{-2}\ d^{-1}$)
Enset landraces								
Agade (H)	8953[a]	3817[a]	43[a]	1095[a]	3.5[a]	587	52540	47.98
Hayiwona (H)	6943[a]	2570[a]	37[a]	1095[a]	2.3[a]	586	40669	37.14
Zobra (H)	8333[a]	3333[a]	40[a]	1095[a]	3.0[a]	637	53078	48.47
Gimbo (H)	8277[a]	3227[a]	39[a]	1095[a]	2.9[a]	612	50631	46.24
Kule (S)	9057[a]	2717[a]	29[a]	1095[a]	2.5[a]	460	41619	38.01
Askala (S)	8890[a]	3747[a]	42[a]	1095[a]	3.4[a]	667	59274	54.13
Derasa Ado (S)	6110[a]	2200[a]	36[a]	1095[a]	2.0[a]	560	34241	31.27
Gossalo (S)	8110[a]	3000[a]	37[a]	1095[a]	2.7[a]	578	46912	42.84
Kiticho (S)	9557[a]	3533[a]	37[a]	1095[a]	3.2[a]	576	55080	50.30
Shewite (S)	9177[a]	3063[a]	33[a]	1095[a]	2.8[a]	577	52940	48.35
Made (S)	9890[a]	3147[a]	32[a]	1095[a]	2.9[a]	470	46496	42.46
Average of *Enset*landarces	7926[a]	2923[a]	34[a]		2.7[a]	523	45386	41.45
Irish potato (*Solanumtuberosum*)	606[b]	121[b]	20[b]	120[b]	1.01	431	2612	21.76
Sweet potato (*Ipomoea batatas*)	698[b]	209[b]	30[b]	150[b]	1.40	569	3972	26.48
Cassava (*Manihotesculenta*)	571[b]	228[b]	40[b]	270[b]	0.85	640	3654	13.53
Taro (*Colocasiaesculenta*)	792[b]	237[b]	30[b]	210[b]	1.13	519	4110	19.57
Yam (*Dioscorea sp.*)	638[b]	172[b]	27[b]	270[b]	0.64	464	2960	10.96
Average of root and tuber crops	661[b]	177[b]	29[b]	193[b]	1.01	525	3462	18.46

[a] Present study; the *Enset* corm yield data are based on the average values of corm yield per plant at a spacing of 3 m^{-2}.

[b]Southern Nations Nationalities and Peoples Regional State, Bureau of Agriculture, Planning Service (SNNPRS, 1998–1999)

(H) = Hadiya zone; (S) = Sidama zone.

The energy production rates for the corms of landraces are calculated from yield and chemical composition data in Table 2 and 4.The energy production rates of root and tuber crops are calculated based on the data of Southern Nations Nationalities and Peoples Regional State, Bureau of Agriculture, Planning Service (SNNPRS, 1998–1999) and food composition table compiled by EHNRI (1995–1997) and Platt (1977)