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Ethiopian rice (*Oryza sativa* Linn.) varieties compared to tef [*Eragrostis tef (Zucc.)* Trotter] grain

Sintayehu LEGESSE [1,2] *

[1] School of Mechanical, Chemical and Materials Engineering, Adama Science and Technology University, P. O. Box 1888 Adama, Ethiopia.
[2] Department of Agronomy and Crop Sciences, Faculty of Agricultural and Environmental Science, University of Rostock, Justus-von-Liebig-Weg 6, D-18059 Rostock, Germany

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*** Corresponding author info:**
Dr. Sintayehu LEGESSE
Email: sintayehu_legesse@hotmail.com
Tel. +251910356372

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Dr. Oudir BOUSSOUM
Dr. Samira MEZIANI
Dr. Mohamed ZAIRI

ABSTRACT

Background: It is really crucial to explore physical properties and chemical composition of the locally cultivated cereal crops to enhance their utilization in various recipes. Moreover, that will fill knowledge gaps in this field and provides advantages for both; producers and consumers who still believe that imported cereals are superior to the locals. **Aims**: This study was intended to investigate the physical properties and chemical composition of the three rice varieties *(Edeget, Nerica-4, and X-jigna)* in comparison to brown tef which are grown in Ethiopia. The evaluation included determination of thousand kernel weight (TKW), hectoliter weight (HLW), moisture, ash, crude fiber, crude fat, crude protein, carbohydrate, Fe, Zn, Ca, and phytic acid contents. **Data Analysis**: The data analysis was conducted using SPSS Version-22. Duncan's multiple range test was used for the mean comparison at $p<0.05$. **Results**: The results revealed that the rice cultivar Edeget showed a higher TKW (39.20 g) than other varieties while brown tef had a TKW of 0.36 g. X-jigna displayed a higher HLW (63.70 kg/hL) than other varieties while the brown tef had 84.48 kg/hL. The ash, crude fiber and fat contents of the brown tef were higher than all the three rice varieties. Nerica-4 had better protein content (9.61%) than other rice varieties and brown tef had a protein content of 9.58%. The iron content of the three rice varieties was virtually null while the brown tef had shown a higher iron content (17.18 mg/100g). Nerica-4 had shown a higher zinc content (3.62 mg/100g) while the brown tef had got higher calcium (91.90 mg/100g) and phytic acid (5 mg/g). **Conclusions**: The study revealed that the physical properties of the three rice varieties were significantly different regardless of the environmental influences.

Keywords: Physical properties, chemical composition, varieties, rice, tef

1. INTRODUCTION

Rice (*Oryza sativa* Linn.) is the second most important cereal grain next to wheat and imparts an essential role in human nutrition especially for developing countries. Rice, constitutes a popular gluten-free source of carbohydrates, and non-allergenic to celiac patients, contains about 7.5% high-quality protein [1]. Moreover, the grain represents a source of income for a large number of people throughout the world. In Ethiopia, rice cultivation has no long history and still, it is not a widely cultivated crop. However, the crop has been used in different forms even before its cultivation was introduced in some parts of the country. Furthermore, it was one of the imported cereal crops in Ethiopia. Rice is utilized to prepare *injera* (alone or by mixing with other cereals such as tef and sorghum), bread, cooked rice and *kinche* (splatted cooked rice). Moreover, it is used for brewing local alcoholic drinks such as *farsso* and *areke*.

However, rice over-consumption results in constipation particularly in children due to its lower fiber content. Additionally, mineral and fat content of rice is reduced compared with other cereals. Therefore, blending rice with other grain such as tef can ameliorate its compositions.

Contrarily, rice grain has come to be one of the important raw materials in the food processing industry because of its inimitable characteristics such as eye-catching white color, lower allergenic, and assimilation [1]. Moreover, rice shows the best expansion property, due to its higher starch composition, and being therefore, appropriate for processing a variety of food products [2].

Tef [*Eragrostis tef (Zucc.)* Trotter] is a stable and fascinating crop which is minute in size, packed with nutrition that supplies the major calorie for the most majorities of Ethiopians [3]. The tef kernel is too small with a mean length and width of 1 to 1.20 and 0.59 to 0.75 mm, respectively [4,5], to isolate the germ from the bran, as a result, the germ and the entire seed is consumed. This is a basic secret behind the greater fiber content and enhanced nutritional benefaction of the tef grain.

The tef grain has an equivalent nutritional composition with the main crops like oats, wheat, barley and rice and superior in some contents [6]. Tef grain has crude protein (11%), carbohydrate (73%), crude fiber (3%), fat (2.5%) and ash (2.8%). The thousand kernel weight of the grain is also in the range of 0.19 to 0.42 g [3].

Nowadays, the tef grain is consumed as a primary food for the over millions of Horn African populations [7]. Basically, the grain is utilized for the preparation of *injera*, a pancake-like fermented flatbread [8] mainly consumed in Ethiopian by almost all age groups. Tef grain, that is gluten-free in nature [6] and has higher iron content as compared to other cereal crops and some legumes [3] constitutes the best source of vitamin B and minerals with a high amount in amino acid compared to other cereal crops like wheat and barley [3] which is comparable to eggs protein except for its lower lysine content [9]. In this paper, I attempted to present the physical properties and the chemical composition of three rice varieties in comparison to brown tef which are locally cultivated in Ethiopia. It was also aimed to escalate the utilization of the locally produced rice varieties in various product developments in combination with the tef to benefit from the combined chemical composition of the grains as well as the reduced cost of the product.

2. MATERIAL AND METHODS

2.1. Experimental materials

Three rice (*Oryza sativa* Linn.) varieties (Edeget, Nerica-4, and X-jigna) and brown tef [*Eragrostis tef (Zucc.)* Trotter] were obtained from Adet Agricultural Research Center (AARC), Bahirdar, and Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia, respectively. The samples were manually cleaned and divided into two parts. One part was reserved for the study of physical properties, while the second one was milled and sieved with 200 μm sieves to get a uniform flour size. All samples were kept in polyethylene bags at room temperature throughout the analysis period. All the samples used in this piece of work were cultivated in Ethiopia (harvest of 2016/17) and the whole experiments were conducted in a very reputable Haramaya University, Ethiopia

2.2. Analytical methods

2.2.1. Grain physical properties

a. Thousand kernel weight (TKW)

TKW was determined as described in AACC [10]. Broken grains and foreign materials were handpicked from the sample. Thousand-grain kernels were counted by seed counter (Numigral II, chopin seed counter, France). The weight of 1000 grains (TKW) was expressed in relation to the dry matter.

b. Hectoliter weight (HLW)

HLW of the grain samples was analyzed as described in AACC [10] method 50 – 10. Dockage free grain sample was prepared and poured into a graduated measuring cylinder. Pouring of the grain sample took place from a height of 15 cm above the cylinder in a regular stream to reduce variation in the degree of packing in a series of trials. The mass of the grain was measured on a digital balance. Finally, the hectoliter weight of the grain sample was calculated and reported as kg/hL.

2.2.2. Proximate compositions

Moisture, ash, crude fat, and crude fiber contents of the samples were analyzed following AOAC [11]. The crude protein [CP (%) = N (%) * 6.25] was calculated after analyzing the nitrogen content by a micro-Kjeldahl method [10]. The total carbohydrate was calculated by differences [100 – (Moisture (%) + Crude ash (%) + Crude protein (%) + Crude fat (%) + Crude fiber (%))] based on Egan *et al.*, [12].

2.2.3. Mineral analysis

The mineral analysis was carried out using atomic absorption spectrophotometer (Model: 210 VGP spectrophotometer, Bulk Scientific, East Norwalk, CT, USA) after wet digestion of about 3 g sample using air-acetylene as a source of energy for atomization [10]. For iron, zinc and calcium determination absorbance were measured at 248.3 nm, 213.8 nm, and 422.7 nm, respectively. Thus, the mineral contents of the samples were estimated from their respective standard calibration curves.

2.2.4. Phytic acid determination

Phytic acid was calculated following the extraction of 0.25g sample in 12.5 mL of 3% trichloroacetic acid, sleet of phytate in the form of ferric phytate by the addition of 4mL of $FeCl_3$ (2 mg/mL) [13] succeeded by phytate phosphorus (Ph-P) analysis [14]. Thus, phytate = P × 3.55 [13].

2.3. Data analysis

All parameters were done in triplicates. The data were examined by analysis of variance (ANOVA) employing IBM SPSS Statistics for Windows, Version 22. Armonk, NY: IBM Corp, USA. The means were compared at $p<0.05$ using Duncan's Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

3.1. Thousand kernel weight (TKW) and hectoliter weight (HLW)

The TKW for each rice varieties and tef grain are shown in Table 1. The TKW of the three rice varieties (Edeget, Nerica-4, and X-jigna), were 39.20, 33.57 and 36.63 g, respectively and that of tef was 0.36 g. The variation in TKW among the rice varieties and the tef grain was statistically significant ($p<0.05$). Rice variety, Edeget has got higher TKW while tef has recorded the smallest TKW. This result showed that the TKW of the grain is clearly a result of the grain size. The values of TKW for rice varieties were in the range of 12.5 to 42.7 g as reported by Yan *et al.,* [15]. The TKW of tef was in the range of 0.19 to 0.42 g which is similar to what was reported by Bultosa [3].

The HLW of Edeget, Nerica-4, and X-jigna rice varieties were 63.57, 59.70 and 63.70 kg/hL, respectively. In previous reports, the HLW of rice was measured in the range of 46.6 - 53.8 kg/hL and this value could reach up to 51.77 - 54.57 kg/hL depending on the selected irrigation method. The HLW of tef was 84.48 Kg/hL which is in agreement with the value reported by Bultosa [3]. Incredibly the tef grain has shown a significantly higher HLW than other rice varieties. This is basically due to the size, shape and packing nature of the grain.

3.2. Proximate compositions

The proximate composition of three rice varieties and tef grain are summarized in Table 1. The moisture contents of Edeget, Nerica-4, and X-jigna rice varieties were 10.10, 10.26 and 10.09%, respectively which is less than 12.30% reported by Hema *et al.* [16]. The moisture content of tef was 10.41%. The moisture content found in tef flour agreed with the mean (10.26%) reported by Bultosa and Taylor [4]. The ash contents of Edeget, Nerica-4, and X-jigna rice varieties were 0.73, 0.64 and 0.94%, respectively which is closer to the mean (0.62%) obtained by Hema *et al.,* [16] and the ash content of tef was 2.94% which was in the range of 1.99% to 3.16% [3]. The ash content of tef grain is higher than rice. Because the grain is too small making difficult to separate the bran from the germ and its bran is proportionally large and the bulk of the flour consists of the bran and germ [3]. The crude fiber content of Edeget, Nerica-4, and X-jigna rice varieties were 0.11, 0.17 and 0.27%, respectively which is closer to the mean value (0.21%) obtained by Sotelo *et. al.,* [17]. Milling of rice to white grain rice generally decreases the fiber content of rice. The crude fiber content of tef was 2.04% which is in agreement with (2.0 to 3.5%) as reported in Bultosa [3]. The tef grain has a better fiber content than most cereal crops due to the smaller size of the grain to remove the bran and the bran is comparably giant [4]. The crude fat content of Edeget, Nerica-4, and X-jigna rice varieties were 1.89, 1.61 and 1.78%, respectively. These results are in the range of 0.9 to 1.97% [18]. Milling of rice removes the outer layer (aleurone layer) of the grain where most of the fats are concentrated [19]. The crude fat content of tef grain was 3.07% which is similar (2.0 to 3.1%) to the reports of Bultosa [3].

The protein content of Edeget, Nerica-4, and X-jigna rice varieties were 8.42, 9.61 and 8.24%, respectively. The obtained results agree with those of Ebuehi & Oyewole [20] (8.3%). The crude protein content of the tef grain was 9.58% which is in the range of 9.4 to 13.3% [3]. Though the rice crop is considered as the lowest protein source than other cereals such as wheat, corn, and barley, its overall protein utilization is the highest [18]. However, the rice varieties used in this study has shown better protein content than previously reported. Rice protein is also known for its lower allergenicity than other grains and legumes protein. Thus, mainly it is used as a source of protein in infant formulas and for celiac patients [1].

The protein in tef is similar to other grains. However, tef grain contains slightly higher methionine, phenylalanine, and histidine than most other grains and lower serine and glycine. The essential amino acid lysine is higher in tef than in most other grains, except rice and oats. The balance of essential amino acids in tef is equivalent to egg protein apart from its lower lysine content [9].

In this study, rice samples contained high carbohydrates ranging from 77.71 to 78.74% that agree with Edeogu *et al.,* [21] and lower in moisture, ash, fiber and fat contents than tef. The total carbohydrate content of tef was 71.35%. The total carbohydrate for tef grain was in close agreement with the reported value of Bultosa [3] (73%).

Table 1: The TKW, HLW and proximate composition of three rice varieties and tef grain

Grains	TKW (g)	HLW (Kg/hL)	Moisture (%)	Ash (%)	Crude fiber (%)	Crude fat (%)	Crude protein (%)	Carbohydrate (%)
Edeget	39.20±0.66^{a}	63.57±0.37^{b}	10.10±0.09^{bc}	0.73±0.04^{c}	0.11±0.00^{d}	1.89±0.02^{b}	8.42±0.17^{b}	78.74±0.27^{a}
Nerica-4	33.57±0.49^{c}	59.70±0.29^{c}	10.26±0.13^{ab}	0.64±0.04^{d}	0.17±0.03^{c}	1.61±0.03^{d}	9.61±0.14^{a}	77.71±0.29^{b}
X-jigna	36.63±0.32^{b}	63.70±0.67^{b}	10.09±0.05^{c}	0.94±0.04^{b}	0.27±0.03^{b}	1.78±0.07^{c}	8.24±0.07 ^{b}	78.69±0.20^{a}
Tef	0.36±0.02^{d}	84.48±1.04^{a}	10.41±0.05^{a}	2.94±0.01^{a}	2.04±0.02^{a}	3.07±0.01^{a}	9.58±0.16^{a}	71.35±0.14^{c}

Values are in Mean ± SD on a dry matter basis. Means within a column with different superscripts are significantly different at P<0.05. Where: TKW is thousand kernel weight and HLW is hectoliter weight.

The carbohydrate of tef grain is virtually starch that displays slow retrogradation property making the grain one of the best alternatives for diabetes patients [4]. Moreover, the gluten-free nature of tef and rice, as well as the smaller size of their starch granules, make the crops to be widely utilized in various forms. Also, imparts to the highly escalating prices of the grains.

3.3. Mineral and phytic acid contents

The mineral and phytic acid content, analyzed for the three rice varieties and brown tef grains, are given in Table 2. The analysis showed that rice had insignificant (p>0.05) iron content (virtually zero). Rice actually has iron, but only in the seed coat which is easily removed during dehulling and/or milling. The iron content of brown tef was 17.18 mg/100g which were found to be less than 37.70 mg/100g [22]; this may be due to contamination and varietal difference.

Table 2: Minerals and phytic acid contents of three rice varieties and tef grain

Grains	Fe (mg/100g)	Zn (mg/100g)	Ca (mg/100g)	Phytic acid (mg/g)
Edeget	0.00^{b}	3.08±0.00^{c}	10.72±0.81^{b}	1.45±0.17^{d}
Nerica-4	0.00^{b}	3.62±0.03^{a}	8.34±0.44^{c}	2.70±0.07^{b}
X-jigna	0.00^{b}	2.71±0.01^{d}	9.91±0.48^{b}	2.43±0.10^{c}
Tef	17.18±0.07^{a}	3.45±0.01^{b}	91.90±0.48^{a}	5.00±0.03^{a}

Values are in Mean ± SD on a dry matter basis. Means within a column with the same superscripts are not significantly different at p>0.05. Where: Fe is iron, Zn is zinc and Ca is calcium.

The zinc content of Edeget, Nerica-4, and X-jigna rice varieties were 3.08, 3.62 and 2.71 mg/100g, respectively which is in a close agreement with Sotelo *et al.,* [17] (1.6 – 3.1 mg/100g). In the current study, tef grain contained 3.45 mg/100g zinc and was higher than 2.86 mg/100g as found by Abebe *et al.*, [22]. The calcium content of Edeget, Nerica-4, and X-jigna were 10.72, 8.34 and 9.91 mg/100g, respectively which was in the range of 3 – 11 mg/100g [23] and the calcium content of tef was 91.90 mg/100g. The calcium content of tef grain was lower than 124.00 mg/100g, reported by Abebe *et al.*, [22]. The phytic acid content of Edeget, Nerica-4, and X-jigna were 1.45, 2.70 and 2.43 mg/g, respectively which is slightly higher than reported by Kennedy *et al.,* [24]. The phytic acid content of grains may vary due to grain varieties, climatic condition, as well as pre and post-processing conditions [25].

The mineral contents of crops may vary along with location and from country to country. For instance, the Fe content of brown rice is 0.022 mg/g in India and 0.012 mg/g in Vietnam [26]. Similarly, Zn shows some disparity about 0.20 mg/100g [27,28].

The minerals' distribution in rice kernels is not uniform. The bran contains about 50% of the minerals and embryo contains 10%. However, both the bran and embryo will be discarded during white rice production. Ash content is a good indicator of mineral compositions and white rice comprises around 28% of the brown rice [29]. Brown rice has about 120 mg/100g phytic acids and this composition varies with location and variety [24,30]. Phytic acid influences the solubility and bioavailability of minerals and proteins by forming a complex with them. Furthermore, it is observed to be one of the considerable factors for iron deficiency anemia due to low bioavailability of iron even in a high iron intake [30].

Phytic acid, well-thought-out as one of the antioxidants in cereals [31], was suggested as a cure for colon cancer [32] and could reduce the noxiousness of certain heavy metals due to its strong chelating ability with metals [33]. The phytic acid content of tef was 5.00 mg/g which is lower than 8.42 mg/g as reported by Abebe *et al.*, [22]. This may be due to grain variety differences.

4. CONCLUSION

The present study showed that the physical properties of the three rice varieties were significantly different regardless of the environmental influences. Because the three rice cultivars were collected from the same site under the same environmental conditions and the same treatments. The three rice cultivars had a higher TKW than brown tef. The brown tef had a higher HLW, due to a high compaction rate mainly because of the smaller grain size. Furthermore, brown tef was found superior in ash, crude fiber and fat content over the three rice varieties. Fe and Ca contents were the highest in brown tef, when Zn was higher in rice cultivar Nerica-4 than brown tef. However, Brown tef showed a higher phytic acid content.

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