

Chemical Composition and Nutritional Quality of Wheat, Teff (Eragrostis tef (Zucc) Trotter), Barley (Hordeum vulgare L.) and Rice (Oryza sativa) -A Review

Dejene Disasa Irge
Madda Walabu University, College Of Natural And Computational Science, Department Of Chemistry, Bale-Robe, Ethiopia; P.Box: 247

Abstract
Overcoming malnutrition in all of its forms-caloric undernourishment, micronutrient deficiencies and obesity requires a combination of interventions in different areas that guarantee the availability of and access to healthy diets. Among the key areas, interventions are required in food systems, public health systems and the provision of safe water and sanitation. The objective of this review is to reveal the different research findings on the composition and nutritional value of four cereals (Wheat, Teff, Barley and Rice) and their products so as to assist further research works on this area. This paper is also presumed to create awareness on chemical composition and nutritional value of some staple food source cereals as one measurement of food quality is the amount of nutrients it contains relative to the amount of energy it provides. Moreover, the review incorporates the relative amounts of dietary constituents in cereals and their products that depend largely on the degree of refinement and other forms of processing.
Keywords: Chemical composition, Nutritional quality, Nutrients, bioavailability

Introduction

Nutrients are substances required by the body to perform its basic functions. Nutrients are used to produce energy, detect and respond to environmental surroundings, move, excrete wastes, respire (breathe), grow, and reproduce. Nutrients that are needed in large amounts are called macronutrients. There are three classes of macronutrients: carbohydrates, lipids, and proteins. These can be metabolically processed into cellular energy. Micronutrients are nutrients required by the body in lesser amounts, but are still essential for carrying out bodily functions. Micronutrients include all the essential minerals and vitamins

Now days, huge number (over three billion) of the world population are afflicted of micronutrient deficiency. Dysfunctional food system, a failure to consistently supply enough of the essential nutrients to address the nutritional demand of susceptible groups, leads to this malnourishment [1]. Enriching staple food sources with micronutrients through plant breading without compromising crop yield, promoting substances that enhance bioavailability (S-containing amino acids, ascorbic acid, etc) or minimizing antinutrient substances (phytate, polyphenolics, etc) that reduces bioavailability are the issues that draw attention during plant breading to address the problem of micronutrient malnourishments [2, 3].

1. Wheat

Wheat is among the leading extensively grown staple food sources in the world. Wheat grains can be ground in to flours, semolina etc. which makes it paramount important in exploiting its nutrients in different food preparations like, pasta, bread and other bakery products[4,5]. Although different wheats have grains that range from almost spherical to long, narrow and flattened shapes, they are generally oval shaped. The grain is usually between 5 and 9mm in length, weighs between 35 and 50mg and has a crease down one side where it was originally connected to the wheat flower. It contains 2-3% germ, 13-17% bran and 80-85% mealy endosperm (all constituents converted to a dry matter basis) [6].

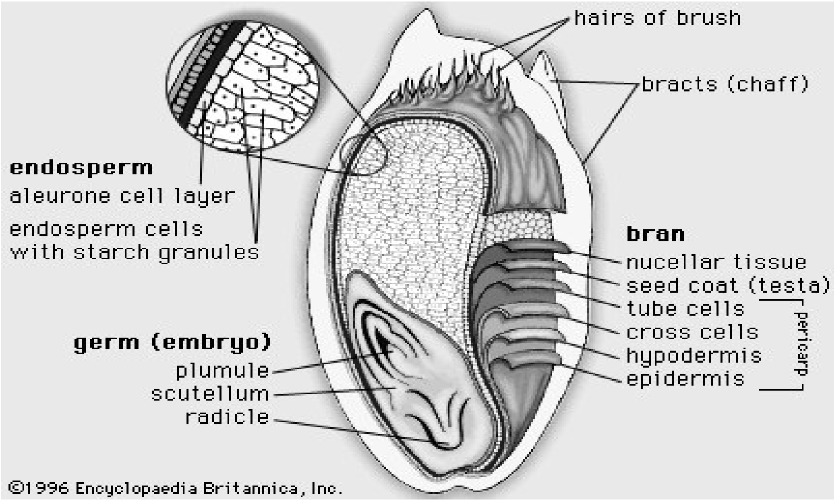

Fig. 1 Wheat grain (from Encyclopaedia Britannica, *http://www.britannica.com*)

The inner part of the grain is protected by a section that contains several layers called Bran, rich in minerals and vitamine B. Majority of bran part consists of water insoluble fibers that enable it protect the inner zone. The chemical composition of this fiber is complex that contains cellulose, pentosans, polymers based on xylose and arabinose, and they are tightly bound to proteins. The mineral content and protein & carbohydrate of dry matter of bran are (72% and 16% respectively). There are large differences between the levels of certain amino acids in the aleurone layer and those in flour. Glutamine and proline levels are only about one half, while arginine is treble and alanine, asparagine, glycine, histidine and lysine are double those in wheat flour [7]. The outer layer of endosperm(aleurone) is rich in protein and enzyme that are important during germination and the inner part is starchy. Moreover, it contains fat(1.5%) and protein(13%), ash(mineral)(0.5) and dietary fibers(1.5%) [6]. Wheat germ is an important source of vitamin E. Wheat germ has only one half the glutamine and proline of flour, but the levels of alanine, arginine, asparagine, glycine, lysine and threonine are double [7].

Protein composition of wheat ranges from 10% - 18% of the total dry matter. The different protein fraction extractable from ground wheat involves albumins (soluble in water), globulins (insoluble in water but soluble in dilute NaCl solution), gliadines (soluble in 70% ethyl alcohol) and glutenins (soluble in dilute acid or NaOH solutions). Most enzymes in wheat grains are found in albumins and globulins parts which are concentrated in seed coats, the aleurone cells and the germ, with a relatively lower concentration in the mealy endosperm. Gliadins and glutenins (the storage proteins) accounts for 75% of the overall protein content unlike globulins and albumins which covers only 25%. The storage proteins are found in the mealy endosperm and are not found in the seed coat layers or in the germ. They produce spongy baked products by retaining gases in the formation of dough but lacks enzymatic activity [6].

Normally, polymerization of glucose molecules forms starch(stored energy form of cereals). Amylose and amylopectins are the two chemically different types of polymers. Amylose is mostly linear in structure, formed through α-1,4-linkage of the monomer unit that contain up to 1000-5000 glucose units. Amylopectine is more of branched one with unit chain containing 20-25 glucose molecules. Under normal circumstances, wheat grain contains around 20%-30% amylose and 70%- 80% of amylopectines [8]. In general, wheat contains starch that vary from 60%-75% of the total dry weight of the grain. In wheat seed, it takes two forms: large(25-40μm) lenticular, and small(5-10 μm), spherical one which occur 15 and 10-30days after pollination. The smaller one comprises about 80% of the case [6].

Fatty acid biosynthesis by mature wheat seeds occurs at different rate. In wheat, lipid synthesis depends on chemical substance Acetyl Coenzyme A. Glycerides, phospholipids, waxes, sphingosine lipids as well as the isoprenoid series are the synthetic product. Under utilization of Malonyl-CoA, NADPH, dehydration and condensation, Palmitic acid is produced which is extended to stearic acid by different reaction [7]. The germ has the highest amount of lipids (11%), but significant amounts are also associated with the bran and the starch and proteins of the endosperm. Mostly of the bound lipids are phosphatidyl choline, phosphatidyl ethanolamine and phosphatidyl serin, as well as lysophosphatidyl derivates, where there is one free hydroxyl group on the glycerol moiety. B-sitosterol, campesterol and C28 and C29 saturated sterols are the principal sterols. Studies show that a high level of linoleate (C18:2) in both the total lipid and the triglycerides from the three fractions with lower amounts of palmitate (C16:0) and oleate (C18:1) [7].

It is defined as lignin plus the polysaccharide components of plants which are indigestible by enzymes in the human gastrointestinal tract [9]. These components are typically divided into two categories.

Soluble dietary fibers: Are those components that are soluble in water and includes pectic substances and hydrocolloids.

Insoluble dietary fibers: Are those components that are insoluble in water and includes cellulose, hemicellulose and lignin. Whole grains are good sources of insoluble fiber.

Arabinoxylan (insoluble type of fiber) is considered to be an optimal substrate for fermentative generation of short-chain fatty acids (SCFAs)—in particular, of butyrate in the colon. Butyrate at high concentrations in the colon is hypothesized to improve bowel health and lower cancer risk by several possible mechanisms [10].

Among the benefits of dietary fiber consumption, protection against heart disease and cancer, normalization of blood lipids, regulation of glucose absorption and insulin secretion and prevention of constipation and diverticular disease are largely pronounced [10, 11, 12]. The increasing awareness of the potential benefits of high-fibre diets has promoted a growing interest for the consumption of whole-grain breads and bran breads. Study showed that whole-wheat flours contain significant amounts of undesirable compounds, such as phytates (myo-inositol hexaphosphate) [13, 14]. Most of the inorganic phosphorus (Pi) present in mature cereal seeds (40–80%) is stored as phytate that forms complexes with minerals such as Ca^{2+}, Fe^{3+}, Zn^{2+} and Mg^{2+} decreasing their bioavailability. Soluble fiber such as (1→3,1→4)-β-D-glucan (referred to as β-glucan), has been shown to have immunostimulating activity as well as effects on the glycaemic, insulin, and cholesterol responses to foods [15, 16].

Micronutrient malnutrition greatly increases mortality and morbidity rates, diminishes cognitive abilities of children and lowers their educational attainment, reduces labor productivity, stagnates national development efforts, contributes to continued high population growth rates and reduces the livelihood and quality of life for all those affected [17]. Among micronutrients, Zn deficiency is occurring in both crops and humans [3]. Zinc deficiency is currently listed as a major risk factor for human health and cause of death globally. According to a WHO report on the risk factors responsible for development of illnesses and diseases, Zn deficiency ranks 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries. Zinc deficiency is responsible for many severe health complications, including impairments of physical growth, immune system and learning ability, combined with increased risk of infections, DNA damage and cancer development [18, 19, 20].

A high risk of tissue hypoxia and heart failure, which can lead to death in young children and pregnant women, is associated with Fe deficiency [21]. Maternal anemia, aggravated by blood loss during child birth, is reported to be responsible for most of the maternal mortality during birth in the world (20% of all maternal deaths are attributed to Fe deficiency anemia [22]. Babies born to mothers that are iron-deficient are commonly stunted and unhealthy. Children suffering from Fe deficiency have poor attention spans, impaired fine motor skills and less capacity for memory [23]. Iron deficiency in pregnant women may cause irreversible damage to fetal brain development leading to irreversible damage to intellectual development in their babies [24]. Iron deficiency in pregnant women is correlated to infant prematurity and low birth weight; this can result in long-term frailties such as immune system dysfunctions and growth failure [25]. As far as concentration of Fe and Zn is concerned, wheat germplasm was studied with respect to the whole grain and environmental interactions on their concentrations [4]. Reports and survey studies revealed that the average concentration of Zn in whole grain of wheat in various countries is between 20 to 35 $mg.kg^{-1}$ [26]. Most of the seed-Zn is located in the embryo and aleurone layer, whereas the endosperm is very low in Zn concentration. Zn concentrations were found to be around 150 $mg.kg^{-1}$ in the embryo and aleurone layer and only 15 $mg.kg^{-1}$ in the endosperm [27]. Fe concentrations (dry weight basis) in wheat grain from plants grown in Mexico in 1994 were 28.8–56.5 $mg.kg^{-1}$ (mean = 37.2 $mg.kg^{-1}$). Clearly, enough genetic variation exits within the wheat germplasm to substantially increase Fe and Zn concentrations in wheat grain. There was a high correlation between grain-Fe and grain-Zn concentrations in the wheat lines studied [28].

Selenium (Se) is known as an essential micronutrient for humans and animals, for its antioxidant, anti-cancer and anti-viral character [29]. One study conducted indicated that soils are frequently low in available Se, and hence the food systems of many countries are deficient in Se[30, 31]). Although Se concentration in wheat grain vary greatly, 0.02–0.60 $mg.kg^{-1}$ for most of the world's wheat, investigation done in Australia showed that wheat supply nearly half of Se intake of most people [32]. In alkaline soils, most Se is present as selenates, which are highly soluble and easily taken up by plants. In acidic, poorly aerated soils, Se occurs mainly as insoluble selenides and elemental Se [30].

2. Teff

The origin of Teff(*Eragrostis tef [Zucc.]) Trotter*)) is believed to be the East African Country, Ethiopia [33]. The Ethiopian traditional food called Enjera(Injera) with the physical characteristics of porous, soft, thin pancake and sour taste is mostly prepared from Teff [34, 35]. Traditionally, Enjera is prepared from a fluid saved from previously fermented dough, water and flour [36]. Studies have shown that Teff protein composition ranges from 10%-12%. One tremendous nature of Teff protein is that it is free from Gluten, the cause for celiac disease [37, 38]. Enrichment in fiber, amino acid composition (like lysine), more mineral content (like phosphorus, iron, copper and calcium) than other cereal grains, and presence of B1vitamin makes Teff preferable [33, 34, 36]. The bioavailability of minerals like Fe and Zn is reduced in the presence of phytic acid and inositol phosphates. Teff grains contain less than one percent of this inhibitory components (528-842mg/100g) [39]. Another study also reported that the amount of phytates in Enjera is remarkably reduced due to fermentation process and its acidity which is supposed to increase the absorbability of different minerals [39]. Besides, the study conducted to determine effect of fermentation on the bio-availability of iron, phosphorus and zinc of teff and wheat indicated that fermentation increased the dialyzable portions of iron from 9% to 24%, phosphorus from 16% to 60% and zinc from 2% to 43% [38]. The sour taste enjoyed in consumption of Enjera and its aroma are reported to be due to the presence of organic acids like lactic acids and volatile fatty acids(C2-C6) which are produced during fermentation[38]. Generation of more B vitamins by fermentation was also reported [36, 39]. A study on the carbohydrate composition of flour milled from red- and white-seeded teff varieties and the changes in carbohydrate content during fermentation showed that non-starch polysaccharides were largely unaffected by fermentation and baking [40]. The iron content of red Teff was found to be higher which renders its Enjera better for prevention of anemia due to parasitic infection Research on celiac disease patients who are using teff reported a significant reduction in symptoms. This is possibly related to a reduction in gluten intake or to an increase in fiber intake. Comparison of antioxidants content between 3 variety Teff flour and their partly and fully fermented Enjera showed that they are reduced with the partly fermented one higher in retention than the fully fermented part [38].

3. Barley

Barley (*Hordeum vulgare* L.) takes the fourth rank in world's cereal production after wheat, maize and rice. There is increasing interest in barley as a food source even if it is mainly used as animal feed. In most European countries, wheat and barley are the most commonly used cereal grains in poultry and pig feeds [43]. It is important source of protein for the nutrition of animals, but deficient in certain essential amino acids when used as food for monogastric animals. Genetic and environmental factors and interactions between the two makes barley greatly variable in chemical composition, nutritive value and bioavailable energy content [44, 45, 46]. The major compositional analysis of barley showed that starch, dietary fibre, and crude protein constitute: 60%, 20%, and 12% of dry matter, respectively [47, 48]. However, considerable variation exists in the dietary fibre and starch content of barley grain which results in a tremendous amount of variation in digestible energy content [48, 49, 50]. High starch content is a desirable quality trait, as it increases the energy level of a feed ration [51]. Barley protein is rich in prolamin storage proteins (hordeins) and has moderate nutritional quality, being particularly deficient in lysine [52, 53]. The increase of protein content is accompanied by decreases in essential amino acids; mainly lysine suggested that nutritional quality of the grain decreases with increasing grain protein contents as an increasing proportion of the nitrogen is incorporated into prolamin storage proteins [52, 54]. Another study showed that nitrogen fertilizer supply increased the crude protein content and digestible crude protein content in barley grain and lowered the lysine content in the protein [45, 55, 56]. The reduced amount of lysine in protein is so slight that the total content of lysine in grain increases due to higher protein content [57]. In study conducted in Poland, to evaluate the chemical composition and nutritive value of four spring hulled barley varieties, the highest constituents for the dry matter were starch (59.1−61.6%), followed by dietary fiber (18.16−21.46%) and crude protein (11.74−13.64%). These three constituents together make up more than 90% of the dry matter of grain. The remaining components of barley grain (ash, ether extract and low molecular weight sugars) were minor constituents. In the same study, contents of pentosans (7.91–9.02%) and cellulose (4.32–4.34%) in barley varieties were analyzed. Pentosans and cellulose are the major non starch polysaccharides (NSPs) in barley. In contrast to starch and sugars, NSPs are not digested by the monogastric animals digestive system, thus reduces metabolizable energy. The study also showed negative correlation between protein content and starch and dietary fiber levels in barley similar to other literatures reviewed in this paper. The variety with lowest protein content had the higher lysine and threonine levels, at about 15% and 9% respectively, than the variety with highest protein content. In addition, the content of total essential amino acids in grain protein of the one with the lowest protein variety was higher (39.5% of total amino acid) than in grain protein of the one with the largest protein variety (37.7% of total amino acid), which suggests that protein quality of barley does not improve with an increased level of protein, which is most often due to increases in the lysine-poor prolamines [58].

4. Rice

Rice (*Oryza sativa*) is one of the most important cereals in human nutrition, consumed by about 75% of the global population [59]. It provides 20 % of the world's dietary energy supply [60]. Rice grain consists of 75-80 % carbohydrate that include starch, glucose, sucrose, dextrin, etc, low fat content after the removal of the bran, 12 % water, good source of thiamine, riboflavin and niacin and low protein content (about 7-10 percent) with a full complement of amino acids. Study conducted in Nigeria on analysis of different rice variety composition indicated that carbohydrate content vary from 51.5 - 86.9 %, crude protein from 1.58 %-7.94%, energy value of 262.94 J/Kg-398.82 J/Kg, fat content 3.5 %- 0.5 %), crude fiber 2.5 % - 1.0 %, moisture content of 9.6 %-5.0 %, and the maximum composition for the minerals Calcium, Magnesium, Phosphorus, Potassium, Sodium to be

(0.13 %), (0.26 %), (0.55 %), (0.23 %), (0.17 %) respectively[61]. In another study conducted in Pakistan on different rice variety and milling fractions, the highest protein content among the variety was 8.80% while among the different milling fraction, the maximum protein content was found in bran (11.71%). In the study, highest ash content among the variety was found 3.79% whereas among different milling fractions it was higher in bran (6.04%). In this regard, Iron, zinc, manganese, copper contents ranged from 0.59 to 3.98 mg/100g, 1.12 to 4.69 mg/100g, 0.51 to 5.12 mg/100g, and 0.28 to1.69 mg/100 g respectively among different milling fractions. The mineral contents ranged from 1.57 to 1.94 mg/100g, 1.44 to 2.97 mg/100g, 1.57 to 2.33 mg/100g and 0.58 to 0.92 mg/100g among different varieties [59]. Rice is a good source of insoluble fiber. Among health benefits of insoluble fibers, reduction of bowel disorders and risk of constipation are mentioned. Even though rice acknowledged in its fiber content, its distribution in different layer of the grain and the way it is prepared matters. For instance, fiber is highest in the bran layer (and the hull) and lowest in milled rice. The bran layer of brown rice provides valuable dietary fiber. One cup (160g) of cooked brown rice contains around 2.4 g of dietary fiber, which equates to 8 % of an average man's daily fiber needs and 9.6% of an average woman's daily fiber needs [60]. Rice protein is highly digestible with excellent biological value and protein efficiency ratio owing to the presence of higher concentration (~ 4 %) of lysine [62]. Digestibility and amino acid composition are among the factors that determine protein quality [63]. The amino acid profile of rice shows that it is high in glutamic and aspartic acid, while lysine is the limiting amino acid [60]. The minerals composition of rice indicated that calcium, magnesium and phosphorus are available along with some traces of iron, copper, zinc and manganese [64]. Minerals are chiefly located in the bran of the rice grain. Therefore, rice can only contribute significantly to the iron supply if it is eaten as brown rice [63]. Varieties of rice with high protein and vitamin (vitamin A) content have been obtained through genetic engineering [64]. Brown rice, hull, white rice and bran are the different fractions following milling which could make it different in chemical composition. For instance, more dietary fiber and nutrients are found in unmilled rice than milled or polished white rice. Massive reduction in composition like 67 % of the vitamin B3, 80 % of the vitamin B1, 90 % of the vitamin B6, 50% of the manganese, 50% of the phosphorus, 60 % of the iron, and all of the dietary fiber and essential fatty acids was observed as a consequence of complete milling and polishing that converts brown rice into white rice [65]. Lipids dietary contribution by rice is usually low which is attributed to the fact that predominant form of rice available in the market is milled rice as this process removes the outer layer where the rice oil is located. Rice lipids, commonly denoted as oil ('rice bran oil') due to its liquid character at room temperature, are characterized by a high nutritional value. The high proportion of unsaturated fatty acids (oleic acid (a monounsaturated acid) and linoleic acid (an essential polyunsaturated fatty acid)) accounting for up to 80 %, causes the liquid consistency of the oil. This unsaturation of rice bran oil is helpful in lowering blood cholesterol level [66].

Conclusion

Cereals (grains) are the staple foods in large parts of the world, supplying most of the energy and bulk in diets. The relative amounts of dietary constituents in cereals and cereal foods depend largely on the degree of refinement and other forms of processing. Many of the cereals (grains) that we consume are refined. Grains are first broken into pieces and then refined, sifting away the bran, germ and, usually, the aleurone layer. This removes most of the fiber, oil, and B vitamins, as well as some per cent of the protein. Polishing, as often performed on rice, removes additional nutrients. Therefore, since different cereal food sources have different nutritional composition, a balanced diet should comprise different cereals. This review paper attempted to explore different research papers studied the chemical compositions, nutritional qualities and alteration in natural constituents as cereals are refined and processed.

References

Welch RM (2005). Food Nutr. Bull. 26: 419-21
Welch RM (2002). J. Nutr. 132: 495S-499S
Welch RM, Graham RD (2004). J. Exp. Bot. 55: 353–364
Welch RM, Graham RD (2002). Plant Soil 245: 205–214
Lindsay DG (2002). Phytochem. Rev. 1: 101–111
Belderok B, Mesdag H, Donner DA (2000). Bread-Making Quality of Wheat. Springer, NewYork
Cornell H (2003). In: Cauvain SP (ed) Bread Making: Improving Quality. Woodhead Publishing, Cambridge.
Konik-Rose Ch, Thistleton J, Chanvrier H, Tan I, Halley P, Gidley M, Kosar-Hashemi B, Wang H, Larroque O, Ikea J, McMaugh S, Regina A, Rahman S, Morell M, Li Z (2007). Theor. Appl. Genet. 115: 1053–1065.
Bermink MR (1994). In: Nielson SS (ed) Introduction to the Chemical Analysis of Foods, Jones and Bartlett Publishers, Boston 169–180,
Fassler C, Arrigoni E, Venema K, Hafner V, Brouns F, Amado R (2006). Eur. J. Nutr. 45:445–453
Weickert MO, Pfeiffer AF (2008). J. Nutr. 138: 439-42

Rave K, Roggen K, Dellweg S, Heise T, Dieck TH (2007). Br. J. Nutr. 98: 929-936.
Lopez HW, Krespine V, Guy C, Messager A, Demigne C, Remesy C (2001). J. Agric. Food Chem. 49: 2657-2662
Lopez HW, Ouvry A, Bervas E, Guy C, Messager A, Demigne C, Remesy C (2000). J. Agric. Food Chem. 48: 2281-2285
Dalmo, RA, Bøgwald, J (2008). Fish Shellfish Immunol. 25: 384-396
Shimizu C, Kihara M, Aoe S, Araki S, Ito K, Hayashi K, Watari J, Sakata Y, Ikegami S (2008). Plant Foods Hum. Nutr. 63: 21-25
Welch RM, Graham RD (1999). Field Crops Res. 60: 1–10
Hotz C, Brown KH (2004). Food Nutr. Bull. 25: 94–204
Gibson RS (2006). Proc. Nutr. Soc. 65: 51–60
Prasad AS (2007). J. Nutr. 137: 1345–1349
Viteri FEV (1998). In: Howson CP, Kennedy ET, Horwitz A (eds) Prevention of Micronutrient Deficiencies. National Academy Press, Washington DC, 45–102.
Maberly GF, Trowbridge FL, Yip R, Sullivan KM, West CE (1994). Ann. Rev. Public Health, 15: 277–301.
Walter T, Peirano P, Roncagliolo M (1997). In: Fischer PWF, L'Abbe MR, Cockell KA, Gibson RS (eds) Trace Elements in Man and Animals – 9. Proceedings of the Ninth International Symposium on Trace Elements in Man and Animals, National Research Council of Canada, Ottawa.217–219,
Gordon N (1997). Brain Dev. 19: 165–170
McGuire J (1993). SCN News 9: 1–10
Cakmak I (2004). IFS Proceedings No. 552, International Fertiliser Society, York 1–28,
Ozturk L, Yazici MA, Yucel C, Torun A, Cekic C, Bagci A, Ozkan H, Braun H-J, Sayers Z, Cakmak I (2006). Physiol. Plant. 128: 144–152
Peleg Z, Saranga Y, Yazici A, Fahima T, Ozturk L, Cakmak I (2008). Plant Soil 306: 57-67
Arthur JR (1999). Proc. Nutr. Soc. 58: 507–512
Lyons GH, Stangoulis JCR, Graham RD (2003). Nutr. Res. Rev. 16: 45– 60
Rayman MP (2002). Proc. Nutr. Soc. 61: 203–215
Alfthan G, Neve J (1996). In: J Kumpulainen and J Salonen (Eds) Natural Antioxidants and Food Quality in Atherosclerosis and Cancer Prevention. Royal Society of Chemistry, Cambridge 161–167.
Uraga K and HV Narasimha(1997). Effect of natural fermentation on the HCl-extractability of minerals from Teff (*Eragrostis teff*). *Bull. Chem. Soc. Ethiop.*; 11: 3-10.
Yigzaw Y, Gorton L, Akalu G and T Solomon(2001). Fermentation of teff *(Eragrostis tef*), grass-pea (*Lathyrus sativus*), and their mixtures: Aspects of nutrition and food safety. *Lathyrus Lathyrism Newslett 2.*
Schneider K and L Anderson(2010). Yield Gap and Productivity Potential in Ethiopian Agriculture: Staple Grains & Pulses. Evans School Policy Analysis and Research (EPAR) of the Bill & Melinda Gates Foundation. *EPAR Brief* No. 98.
Ashenafi M (2006). A review on the microbiology of indigenous fermented foods and beverages of Ethiopia. *Ethiop. J Biol. Sci.*; 5: 189-245.
Abiyu HT, Woldegiorgis AZ and GD Haki(2013). Preparation of *Injera* from Pre-fermented Flour: Nutritional and Sensory Quality. *Int. J. Sci. Innov. Discov*.; 3 (1): 165-175.
Gamboa PA and LV Ekris (2008). Teff: survey on the nutritional and health aspects of teff (*Eragrostis tef*). 319-367.
Blandino A, Al-Aseeri ME, Padilla SS, Cantero D and C Webb (2003). Review: Cereal-based fermented foods and beverages. *Food Res. Int.*; 36:527–543.
Umeta M, West CE and H Fufa (2005). Content of zinc, iron, calcium and their absorption inhibitors in foods commonly consumed in Ethiopia. *J. Food Compos. Analysis.***18**: 803-817.
Hrušková M, Švec I and I Jurinová (2012). Composite Flours-Characteristics of Wheat/Hemp and Wheat/Teff Models. *Food Nutr. Sci.* 3: 1484-1490.
Bultosa G(2007). Physicochemical Characteristics of Grain and Flour in 13 Tef. *J. Appl. Sci. Res.* 3(12): 2042-2051.
Bergh, M. O., A. Razdan and P. Aman, (1999). Nutritional influence of broiler chicken diets based on covered normal, waxy and high amylose barleys with or without enzyme supplementation. *Animal Feed Science and Technology,* 78: 215-226.
Zhang, W. J., L. D. Campbell and S. C. Stothers (1994). An investigation of the feasibility of predicting nitrogen-corrected true metabolizable energy (TMEn) content in barley from chemical composition and physical characteristics. *Canadian Journal of Animal Science,* 74: 355-360.
Valaja, J., K. Suomi, T. Alaviuhkola and T. Mela, (1997). Effects of Variety, soil, type and nitrogen fertilizer supply on the nutritive value of barley for growing pigs. *Agricultural and Food Science in Finland*, 6: 295-303.

Andersson, A. A. M., C. Elfverson, R. Andersson, S. Regne´r and P. Åman, (1999). Chemical and physical characteristics of different barley samples. *Journal of Science of Food and Agriculture,* 79: 979–986.

Åman, P. and C. W. Newman, (1986). Chemical composition of some different types of barley grown in Montana, USA. *Journal of Cereal Science,* 4:133–141.

Oscarsson, M., R. Andersson, A. C. Salomonsson and P. Åman, (1996). Chemical composition of barley samples focusing on dietary fibre components. *Journal of Cereal Science,* 24: 161-169.

Reynolds, W. K., C. W. Hunt, J. W. Eckert and M. H. Hall, (1992). Evaluation of the feeding value of barley as affected by variety and location using near infrared reflectance spectroscopy. *Proceedings, Western Section, American Society of Animal Science*, 43: 498-501.

Bowman, J. G. P., T. K. Blake, L. M. M. Surber, D. K. Habernicht and H. Bockelman, (2001). Feed-quality variation in the barley core collection of the USDA national small grains collection. *Crop Science*, 41: 863-870.

Hunt, C. W., (1996). Factors affecting the feeding quality of barley for ruminants. *Animal Feed Science and Technology*, 62:37–48.

Pomeranz, Y., G. S. Robbins, R. T. Smith, J. C. Craddock and J. T. Gilberston, (1976). Protein content and amino acid composition of barley from the world collection. *Cereal Chemistry,* 53: 497–504.

Jørgensen, H., V. M. Gabert and J. A. Fernández, (1999). Influence of nitrogen fertilization on the nutritional value of highlysine barley determined in growing pigs. *Animal Feed Science and Technology,* 79: 79-91.

Jacyno, E., (1989). Nutritive value of barley varieties and feed mixtures containing them in pigs feeding. *Ph.D. dissertation, Agricultural University in Szczecin, Poland*.

Shewry, P. R., (2007). Improving the protein content and composition of cereal grain. *Journal of Cereal Science,* 46: 239–250.

Fuller, M. F., A. Cadenhead, D. S. Brown, A. C. Brewer, M. Carver and R. Robinson, (1989). Varietal differences in the nutritivevalue of cereal grains for pigs. *Journal of Agricultural Science, Cambridge,* 113:149–163.

Thomke, S., (1976). The feeding value of barley for growing-finishing swine. IV. The effect of differences in protein content caused by N fertilization, and prediction of protein content. *Zeitschrift für Tierphysiologie, Tierernährung und Futtermittelkunde,* 36: 156-170.

W. BIEL and E. JACYNO, (2013). chemical composition and nutritive value of spring hulled barley varieties. *Bulgarian Journal of Agricultural Science, 19:721-727*

F.M. Anjum, Imran Pasha, M. Anwar Bugti and M.S. Butt, (2007). Mineral composition of different rice varieties and their milling fractions. Pak. J. Agri. Sci., Vol. 44(2).

FAO (2006.) Food and Agriculture Organization / International Rice Research Institute. Food and Nutrition Series, FAO Rome, 26

Oko A. O., Ubi B. E., Efisue A. A., Dambaba N. (2012). Comparative Analysis of the Chemical Nutrient Composition of Selected Local and Newly Introduced Rice Varieties Grown in Ebonyi State of Nigeria. International Journal of Agriculture and Forestry, 2(2): 16-23.

FAO/WHO (1998). Obesity: Preventing and managing global epidemic, WHO technical report, Geneva, Switzerland,11-12.

M. Frei and K. Becker, (2003). Studies on the in vitro starch digestibility and glycemic index of six different indigenous rice cultivars from the Philippines, Journal of Food Chemistry, 83, 395-400.

M. Yousaf, (1992). Study on some Physico-chemical characteristics affecting cooking and eating qualities of some Pakistani Rice Varieties, M.Sc. Thesis Department of Food Technology, University of Agriculture Faisalabad, Pakistan.

A. H. Ensminger and M. K. Ensminger, (1986). Food for Health: A Nutrition Encyclopedia, Pegus Press, Clovis, California, 106-108.

K. Tanaka, M. Ogawa and Z. Kasai, 1977, The rice scutellumII, Journal of Cereal Chemistry, 54, 684-689

C. O. Edeogu, F. C. Ezeonu, A. N. C. Okaka, C. E. Ekuma, and S. O. Elom, (2007). Proximate composition of staple food crops in Ebonyi State (South Eastern Nigeria), International Journal of Biotechnology and Biochemistry, 3(1), 1-8