Food Chemistry 159 (2014) 374–380

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Nutritional quality of grains of sorghum cultivar grown under different levels of micronutrients fertilization

Suha O. Ahmed [a], Adel Wahab H. Abdalla [b], Tomoe Inoue [c], Ann Ping [d], Elfadil E. Babiker [e,*]

[a] Department of Food Chemistry, Food Research Center, Ministry of Science and Communication, Khartoum North, P.O. Box 213, Shambat, Sudan
[b] Department of Crop Production, Faculty of Agriculture, University of Khartoum, Khartoum, Sudan
[c] Laboratory of Arid Land Plant Resources, Arid Land Research Center, Tottori University, Japan
[d] Department of Plant Eco-physiology, Arid Land Research Center, Tottori University, Japan
[e] Department of Food Science and Nutrition, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

ARTICLE INFO

Article history:
Received 11 December 2013
Received in revised form 4 March 2014
Accepted 8 March 2014
Available online 17 March 2014

Keywords:
Sorghum
Micronutrients
Fertilization
Protein
Amino acids

ABSTRACT

A pot experiment was carried out to investigate the effect of different levels of micronutrients (0, 2, 4, and 8 g/5 kg soil) and a fixed amount (6 g/5 kg soil) of macronutrients fertilizer on the antinutrients content, protein content and digestibility, total and extractable macro- and micro-elements, amino acid content and score of grains of sorghum cultivar (Gadambalia) grown for two consecutive season. Protein content and essential amino acids composition of sorghum grains significantly ($P \leqslant 0.05$) increased with micronutrients level for both seasons. Tannins and phytate contents dropped significantly ($P \leqslant 0.05$) with a concomitant increase in protein digestibility, macro- and micro-elements extractability for both seasons and treatments. The content of macro- and micro-elements of the grains increased with micronutrients level during both seasons. The essential amino acids scores of the grains were significantly ($P \leqslant 0.05$) increased for both seasons and treatments.

1. Introduction

Sorghum (*Sorghum bicolor* L. Moench) is considered as a most important food crop in the world following wheat, rice, maize and barley (FAO., 1997). Grain sorghum represents the staple food for a large population of Africa, India and the semi-arid parts of the tropics (FAO, 1997). It is commonly consumed by the poor mass of many countries and forms a major source of proteins and calories in the diet of large segments of the population of India and Africa (FAO, 1997). Besides being a staple food, it is also used as feed for animals and it is an industrial raw material; its straws provide fodder, fuel, shelter and raw material for syrup production. Grain sorghum is the leading cereal crop in the Sudan and acts as a principal source of energy, protein, vitamins and minerals for the low income population living in Sudan (Abdelseed, Abdelwahab, AbuelGasim, Isam & Babiker, 2011). Most of sorghum cultivars grown in Sudan contained only 9–11% protein content and most of the amino acids are limited (Elbashir, Mustafa, Eltinay & Babiker, 2008), which is critical for determining the nutritional value of foods. It is evident that the nutritional importance of a given food/feed stuff depends not only on nutrient composition or content, but also on the amount utilized by consumers (Vijayakumari, Siddhuraju, Pugalenthi, & Janardhanan, 1998). Soil pH influences solubility, concentration, ionic form and mobility of elements and consequently acquisition of such elements by plants (Fageria, Baligar, & Wright, 1997). The deficiency of essential micronutrients induces abnormal plant tissue pigmentation, size, and shape, which causes low leaf photosynthetic rates, and leads to various undesirable outcome, such as grain yield and composition (Masoni, Ercoli, & Mariotti, 1996). Today, although the production of energy and protein appears to be adequate to feed the developed world, agriculture systems in many developing countries still do not provide enough nutrients to meet human needs (Welch & Graham, 2004). Different approaches have been tried to improve the nutritional value of sorghum grain such as fermentation and malt pretreatment (Abdelhaleem, Eltinay, Mustafa, & Babiker, 2008) and supplementation with legumes (Asma, Babiker, & Eltinay, 2006), cluster bean (ELbashir, Mustafa, Eltinay, & Babiker, 2008) and pigeon pea (Abdallah, Babiker, Yagoub, & Isam 2010) as well as conventional breeding (Abdelseed, Abdelwahab, AbuelGasim, Isam & Babiker, 2011). Moreover, previous research only focused on the effect of micronutrients fertilization on total yield. Therefore, the objective of this study was to investigate the different effects of the varying micronutrients levels and fixed level of macronutrients fertilizers on the grains nutritional quality of sorghum cultivar (*Gadambalia*) grown under controlled conditions for two consecutive seasons.

* Corresponding author. Tel.: +966 114693311.
E-mail address: ebabiker.c@ksu.edu.sa (E.E. Babiker).

http://dx.doi.org/10.1016/j.foodchem.2014.03.033
0308-8146/

2. Materials and methods

2.1. Materials

Grains of sorghum (*Sorghum biocolor* L. Monech) cultivar (Gadambalia) were obtained from the Department of Agronomy, Faculty of Agriculture, University of Khartoum, Shambat, Sudan. Micronutrients blend (MB) was obtained as a mixture of 14% water soluble Mo + 0.3% water soluble Mn + 0.3% water soluble B + 1.2% FeS + 0.02% Cu_2SO_4 + 0.02% $ZnSO_4$ + 0.004% $(NH_4)_6[Mo_7O_{24}]\cdot 4H_2O$, and macronutrients fertilizers (MF) ($N–P_2O_5–K_2O$) were donated by the Arid Land Research Center, Tottori University, Japan. Unless otherwise stated all the reagents used in this study were of analytical grade.

2.2. Plant experiment

A trial experiment was carried out to optimize the conditions suitable for minerals absorption. The conditions tested are pH, environment and soil temperature and soil type. After adjustment of the conditions, the final experiments were carried out (2010 and 2011) at the Experimental Station of the Faculty of Agriculture, University of Khartoum, Shambat (latitude 15°40′N and longitude 32°32′E). The soil was sandy clay (82% sand and 18% clay) with pH of 7.2. The grains of the cultivar were seeded in pots with three grains per pot and after germination, were reduced to one plant per pot. Four doses (0, 2, 4 and 8 g/5 kg soil) of MB were applied to each pot. Beside micronutrients, all treatments received MF ($N–P_2O_5–K_2O$) at a fixed dose of 6 g/5 kg soil. After addition of fertilizer and germination of the seeds, the pH of the soil dropped to 5.7 and temperature between 20 and 25 °C. To avoid water loss, the pots were watered under controlled conditions (weight difference). Each experiment was arranged in a factorial design with four replicates. At the end of each season, the grains were collected, sun dried, cleaned from dirt and broken grains and then ground to pass a 0.15 mm screen and stored at 4 °C.

2.3. Protein content determination

The protein content of the grains was determined according to AOAC (1995).

2.4. Tannin determination

Quantitative determination of tannins was carried out using the modified spectrophotometric vanillin-HCl method according to Price and Butler (1978) by using 200 mg sample. A standard curve was prepared and results were expressed as catechin equivalents, i.e. amount of catechin (mg per ml) which gives a colour intensity equivalent to that given by tannins after correcting for blank.

2.5. Phytic acid determination

Phytic acid content was determined by the method described by Wheeler and Ferrel (1971) by using 2.0 g dried sample. A standard curve was prepared and results were expressed as $Fe(NO_3)_3$ equivalent. Phytate phosphorus was calculated from the standard curve assuming a 4:6 iron to phosphorus molar ratio.

2.6. In vitro protein digestibility (IVPD) determination

IVPD was carried out using single enzyme (pepsin) digestion according to the method of Maliwal (1983). The digestibility was calculated using the following equation:

$$\text{Protein digestibility } (\%) = \frac{\text{N in supernatant} - \text{N in pepsin}}{\text{N in sample}} \times 100$$

2.7. Total minerals determination

Minerals were extracted from the samples by the dry ashing method described by Chapman and Pratt (1982). About 2.0 g of sample was acid-digested with diacid mixture (HNO_3:$HClO_4$, 5:1, v/v) in a digestion chamber. The digested samples were dissolved in double-distilled water and filtered (Whatman No. 42). The filtrate was brought to 50 mL with double-distilled water and was used for determination of total calcium, phosphorus and iron. Calcium was determined by a titration method. Iron was determined by atomic absorption spectrophotometer (Perkin-Elmer 2380). Phosphorus was determined by spectrophotometric method using molybdovanadate and the absorbance was measured at 730 nm.

2.8. HCl extractability of minerals (in vitro bioavailability)

Minerals in the samples were extracted by the method described by Chauhan and Mahjan (1988). About 1.0 g of the sample was shaken with 10 mL of 0.03 M HCl for 3 h at 37 °C and then filtered. The clear extract obtained was oven-dried at 100 °C and then acid digested. The amount of extractable minerals was determined by the dry ashing method described by Chapman and Pratt (1982). HCl extractability (%) was determined as follows:

$$\text{Mineral extractability } (\%) = \frac{\text{Mineral extractable in } 0:03 \text{ NHCl } (\text{mg}/100\text{g})}{\text{Total minerals } (\text{mg}/100\text{g})} \times 100$$

2.9. Amino acids composition

The amino acids composition of the samples was determined on hydrolyzed protein using amino acids analyzer (Sykam-S7130, Tokyo, Japan) based on high performance liquid chromatography technique. Sample hydrolysates were prepared following the method of Moore and Stain (1963). About 200 mg of the sample was taken in a hydrolysis tube. Then 5 mL of 6 N HCl was added and the tube tightly closed and incubated at 110 °C for 24 h. After incubation, the solution was filtered and 200 mL of the filtrate was evaporated to dryness at 140 °C for 1 h. The hydrolysates after dryness were diluted with 1.0 mL of 0.12 N citrate buffer (pH 2.2). Aliquot (150 μl) of the sample hydrolysates was injected in an action separation column at 130 °C. Ninhydrin solution and an eluent buffer (solvent A, pH 3.45 and solvent B, pH 10.85) were delivered simultaneously into a high temperature reactor coil (16 m length) at a flow rate of 0.7 ml min^{-1}. The buffer/ninhydrin mixture was heated in the reactor at 130 °C for 2 min to accelerate chemical reaction of amino acids with ninhydrin. The products of the reaction mixture were detected at wavelengths of 570 and 440 nm on a dual channel photometer. The amino acids composition was calculated from the area under the curve of the standards and expressed as mg/100 g sample.

2.10. Essential amino acid (EAA) score determination

The essential amino acid (EAA) score was determined by applying the formula:

$$\text{AAS score } \% = \frac{\text{g of EAA in 100 g test protein}}{\text{g of EAA in 100 g FAO/WHO reference pattern}} \times 100$$