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Amaranthus Caudatus Production and Nutrition Contents for Food Security and Healthy Living in Menit Shasha, Menit Goldya and Maji Districts of Bench Maji Zone, South Western Ethiopia

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Abstract

Amaranth is a reliable and low risk cereal that grows on a wider ecology under moisture stress and waterlogged areas with few plant diseases and grain storage pest problems. The investigation evaluates the three types of Amaranthus caudatus Production and Nutrition Profile in Menit shasha, Menit Goldya and Maji Districts of Bench Maji Zone, South Western Ethiopia. Sample sizes of Amaranth producer households considered during the survey were 120. The protein and fat content of the amaranth falls in the range of 14.12-16.64 and 9.39 to 6.86g/100g, respectively. The available carbohydrate content of red amaranth was less than that of white and red colored amaranth. The amount of ash in the three types of amaranth whole seeds was in the range between 2.99 to 3.30, the maximum being for the red colored amaranth and the minimum for white colored amaranth. The content of fiber was about twice higher in red amaranth than in the two others. The content of total iron was highest in Brown colored amaranth, however for calcium and magnesium the highest was in red colored amaranth. Important minerals in the grain amaranth identified in this study included potassium (420mg/100g); calcium (173.55mg/100g); and magnesium (293.48mg/100g). The content of phytate in raw amaranth was 360.21, 334.49 and133.55mg/100g, for white, brown and red amaranth respectively. Therefore, designing strategies to degrade the high phytate content in amaranth is indispensable. The amount of total tannins in the brown colored amaranth was 58.36mg/100g. These values are higher than that obtained in red amaranth: 39.05mg/100g and white amaranth: 20.54mg/100g, respectively as colored substances contains high level of bioactive compounds than pale seeded once. Generally; the proximate contents of protein, carbohydrate, fat, ash and energy showed that the grain amaranth in this study was full with balanced nutrients that could enhance healthy living and food security. Zinc and iron stabilize immune function and reduce complications from HIV/AIDS and anemia diseases respectively; and magnesium and manganese that are crucial for infants growth and development. More research efforts are needed on production, inclusion in diets, consumer behavior and market acceptability of amaranth based products in order to contribute to the efforts of addressing food security, poverty reduction, nutritional, and medicinal needs of vulnerable communities.

Keyword: Grain amaranth; Nutrition value; Utilization; Well-being

Introduction

The species Amaranthus belongs to the family of Amaranthaceae and believed to have originated from Central and South America [1]. It produces a large amount of biomass in a short period of time [2] and therefore has the potential to contribute to a substantial increase in world food production. Amaranth is a pseudo cereal with excellent nutritional and functional properties, capable of withstanding extreme climate and soil conditions [3]. Studies done so far indicated that the crop has excellent nutritional profile with high level of protein, minerals, and fat as compared to the common utilized cereals [4-6]. Moreover, it has excellent amino acid and fatty acid profiles with high amount of lysine and high percentage of unsaturated fatty acids [7,8].

Amaranth was declared as one of the future promising crop to feed the global population [9]. Due to its high nutritional value as well as some agricultural advantages such as relative high grain yield, resistance to drought, and short production time, amaranth has got the attention of many researchers. In the past years it has been used in many places of the country, particularly in the Southern Nations Nationalities and Peoples Region (SNNPR), mainly for its medicinal purpose especially for mothers at their early stage of lactation with the assumption that it strengthens their bones (personal communication). In some places of the country, grain amaranth is fermented to make alcoholic beverage, e.g. beer ('tella') in Benishangul-Gumuz region and another local beverage known as 'Chaqa' in konso. The cooked seeds could also be made into porridge, and ground seeds are mixed with 'teff' to prepare pancake-like bread ('injera') [10].

The crop is mostly grown and consumed in the humid area of Oromiya, Benashangule Gumuz, Gambella and SNNPRS. Extensively in Benchi Maji area, it is the staple food of Meenit, Dizei and Surma peoples [11]. Amaranth is mainly grown in the Benchi Maji Zone in Menit shasa, Meenit Goldya, Maji and Yeki woreda. Three varieties of Amaranths (white, red and black) are grown in Ethiopia. It is cultivated three times per year as a single or inter-cropping with maize or sorghum. It is drought resistant and can easily be cultivated with a minimum amount of water [11]. Presently the production of amaranths is 2527 hectare while the zone of Bench Maji takes the highest share, which is 689 hectares from the total [12]. There is no research and extension effort made so far to promote its production. Therefore, the aim of the present study was to determine agronomic practices, the status of grain amaranth production, the proximate composition, minerals and mineral absorption inhibitors of three different types of Amaranthus caudatus grains cultivated in SNNP region, Ethiopia.

Material and Methods

Description of the study area

The research was conducted in Menit shassa, Menit Goldya, and Maji woreda. The area receives mean annual rainfall ranging from 1500 to 1800mm (an average 1692mm) per year and has 15 ℃ to 27 ℃ range of temperature annually and the soil is loam or silty-loam soil type. The main food crops in this Zone include maize, godere (taro root), and enset, while sorghum, teff, wheat and barley are cultivated to a significant extent. Cash crops include fruits (bananas, pineapples, oranges) and spices (e.g. coriander and ginger). However, coffee is the primary cash crop.

Sampling Strategy

The study was consisting of a questionnaire on production practices that farmers deemed representative of amaranth growing areas on their particular farm. A total of 40 farmers were interviewed in each District. Interview respondents were selected through a non-probabilistic survey sampling method known as snowball or chain referral sampling [13]. Snowball sampling depends on referrals from initial respondents to generate further respondents and is often used when a sampling characteristic (such as production of grain amaranth) is rare and where the desired characteristic may be difficult or costly to find. Though snowball sampling may facilitate the location of appropriate respondents, this comes at the cost of introducing bias into the results, as the sample is unlikely to accurately represent the survey population as a whole. Nevertheless, snowball sampling is frequently used in qualitative sociological research [14]. The interview process generally may last for two hours on average, with nearly all farm visits including an inspection of current or previous amaranth fields.

Grain sample preparation and analysis

The currently produced three different types of amaranthus grains i.e. white, red and brown in color were collected from the farmers living from three districts namely Menit Goldya, Menit Shasha, and Maji woreda, in Bench Maji Zone, Southwestern, Ethiopia in February 2017. The grains were sorted to remove immature seeds, cleaned and washed to remove sand and soil. The washed seed was sun dried and equal amount of the three district samples was mixed to prepare a composite sample for each amaranth types.

The proximate analysis for amaranth varieties was performed according to the method of the Association of Official Analytical Chemists' [15]. Mineral and trace elements sample digestions were undertaken using a closed-vessel microwave digestion system. To assess possible contamination, blank solutions were prepared containing the same reagents and using the same procedure as the samples and standards.

Methods of data collection and data analysis

In this study, both the primary and secondary data were used. The primary data were collected through a questionnaire survey and key informant interviews. To generate relevant secondary data on production and consumption, data were collected from different published and unpublished sources such as government institutions; the Bureau of Agriculture and Rural Development (BoARD) and websites were referred. To facilitate the collection of both primary and secondary data, preliminary information about the study area were obtained from the Bureau of Agriculture and Rural Development (BoARD) to find important information for questionnaire development.

Descriptive statistics like mean, standard deviation, ratio, frequency and percentiles were used in order to explain and interpret the data obtained from sampled households. The collected raw data were analyzed by applying the Micro-soft Office Excel and the Statistical Package for social Science (SPSS) version 23.

Result and Discussion

Socio-economic characteristics of amaranth producers

Sample size of Amaranth producer households considered during the survey was 120. Proportionally, of the total cultivated land amaranth producers owned 1.84% of cultivated land used for the production of amaranth. The result also shows that farming is the main source of households' income for both woredas sample households. The average quantity of amaranth produced per sample households was 9853.00kg but the average value for home consumption was 7553kg. In the study area, of the total volume of crops produced, 198,984.50kg were supplied to the market. Sample respondents also reported that the amount of amaranth produced per household head was 9853kg for amaranth. In the study area, of the total volume of

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amaranth produced, 23.4% of amaranth was supplied to the market.

Proximate composition of amaranth grains

The grains of the three different types of amaranth were differing in shape. The white and red types were flattened and the brown one had a lenticular shape. Amaranth is often called the "small giant" because of its small grains with high nutritive value. Table 1 shows the proximate composition of three different types of Amaranthus caudatus grain. The protein and fat content of the amaranth falls in the range of 14.12-16.64 and 9.39 to 6.86g/100g, respectively. The results were in agreement with previous reports by Kaur et al. [16] and He et al. [17]. The fat content in amaranth grain was superior to most conventional cereals such as wheat, maize and teff. The proximate composition values obtained in this study had similar or better values compared to findings.

The available carbohydrate content of red amaranth was less than that of white and red colored amaranth. This is associated with the high level of dietary fiber in the red amaranth as all the three amaranth types contain comparable quantities of other nutrients. The amount of ash in the three types of amaranth whole seeds was in the range between 2.99 to 3.30, the maximum being for the red colored amaranth and the minimum for white colored amaranth. This result fell in the range reported by Kaur et al. [16] (Table 1).

Table 1: Proximate composition of three types of raw *Amaranthus caudatus* grains.

Sample	Protein	Fat	Carbohydrate	Ash	Moisture	Fiber	Fatty Acid	Energy
White Amaranth	14.96	6.86	58.33	2.99	12.14	4.72	0.35	354.86
Red Amaranth	16.64	6.42	45.7	3.3	16.61	11.33	1.26	307.17
Brown Amaranth	14.12	6.39	55.64	3.03	16.24	4.57	1.57	336.59

Some of these health benefits of fiber are to aid proper removal of stool, lowering the blood cholesterol and glucose levels, modification of gut microecology, weight management, preventing from colon cancer, GI disease etc. The content of fiber was highest for red amaranth (11.33g/100) followed by the white (4.72g/100g) and Brown (4.57g/100g). The content of fiber was about twice higher in red amaranth than in the two others (Table 1). Red Colored amaranth is known to have high amount of dietary fiber [6]. The results of the fiber in raw samples were also in agreement with the report by Mustafa et al. [4] and higher than the amount of insoluble dietary fiber present in Amaranthus hypochondriacus reported by Czerwinski et al. [18]. The difference between fiber was comparable in white and Brown amaranth but higher in red amaranth (Table 1). As concluded in findings, the balance of carbohydrates, fats, and protein allow amaranth the opportunity to achieve a balanced nutrient uptake with lower amounts of consumption than with other cereals. And that this could also be one of the pathways towards solving the macro - and micronutrient deficiencies experienced in ethiopia. Also, Tagwira et al., [19] reported that consumption of grain amaranth provide nutritional and health benefits that include general improvement in well-being such as severely malnourished children recovered; and prevention and improvement of specific ailments and symptoms like people that were wasted by HIV/AIDS increased in their body mass index. Thus the proximate contents of protein, carbohydrate, fat, ash and energy showed that the grain amaranth in this study was encumbered with balanced nutrients that could enhance healthy living and food security.

Mineral contents of amaranth grains

The content of total iron was highest in Brown colored amaranth, however for calcium and magnesium the highest was in red colored amaranth (Table 2). Zinc contents in the three types of amaranth were lower than that reported by Mustafa et al. [4] & Nascimento et al. [20]. As they indicated, people with AIDS are almost universally deficient of zinc, which contributes significantly to the continued decline of their already damaged immune systems. Therefore, consumption of grain amaranth could stabilize their immune function and reduce complications from the disease. The iron content in raw samples exhibited huge variation ranging between 20.82-35.09mg/100g and fell in the range reported by Mustafa et al. [4] but higher than that reported by Nascimento et al. [20]. Also, the results in this study showed that amaranth grain is a good source of iron (35.09 mg/100g) compared with the 16.8-21.0mg/100g obtained by Stephen et al., (2013) and iron (13.0 mg/100g) and zinc (3.09 mg/100g) obtained by Mburu, et al., (2012) [. It was pointed out that Iron is required by a number of enzymes that are required for oxygen metabolism and its deficiency anemia reduces oxygen-carrying capacity and interferes with aerobic functions.

Calcium content also exhibited huge variation among the three types of amaranth (139.90-173.55mg/100g in raw samples). Generally, red amaranth had highest mineral contents, particularly calcium and magnesium which was nearly twice those measured in the white and brown amaranth. The result was not far from the reports by Pedersen et al. [6] & Mustafa et al. [4]. The amount of Mg was in the range of 261.25-293.48mg/100 g for raw samples and fell in the range reported by Mustafa et al. [4] and higher than that reported by Nascimento et al. [20]. Important minerals in the grain amaranth identified in this study included potassium (420mg/100g); calcium (173.55mg/100g); and magnesium (293.48mg/100g) which were higher values except for calcium

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when compared to those obtained from Mburu, et al., (2012); grain amaranth product that had potassium (324.4mg/100g), calcium (189.1mg/100g), magnesium (219.5mg/100g) respectively. They concluded that considering amaranth grain product fed to infant three times a day, at a reconstitution of 15% product, the levels of magnesium and manganese were far above the recommended intakes. Therefore, the grain amaranth in this study is loaded with essential minerals especially zinc and iron that could stabilize immune function and reduce complications from HIV/AIDS and anemia diseases respectively; and magnesium and manganese that are crucial for infants growth and development (Table 2).

Table 2: Mineral content of three types of raw A*maranthus caudatus* grains.

Sample	Iron	Calcium	Magnesium	Zinc	Manganese	Copper	Sodium	Potassium
White Amaranth	20.82	139.9	278.33	3.09	3.02	0.26	21.21	359.45
Red Amaranth	34.6	173.55	293.48	2.62	4.19	0.3	31.21	420.3
Brown Amaranth	35.09	153.08	261.25	2.53	4.1	0.16	9.67	322.38

Mineral absorption inhibitors

Cereals, pulses and legume-based commodities are rich and low-cost sources of nutrients for a large part of the World's population. But their nutritive value is limited by, the presence of absorption inhibitors such as phytates, tannins/ polyphenols, dietary fibers etc. Amaranth has attracted a great deal of interest in recent decades due to its valuable nutritional and agricultural characteristics. However, the nutritional significance has been limited by the presence of high level of phytic acid [21,22]. Phytic acid mainly chelates divalent metal ions such as iron, zinc, calcium, magnesium and manganese, making them unavailable for absorption in humans and monogastric animals. Moreover, amaranth grain contains about 60% starch [3] and the presence of such high amount of starch will influence the energy density by forming a thick viscous porridge at low dry matter content. As a result, applying techniques that could partially hydrolyze the starch and/or degrade the phytic acid will significantly improve both the energy density and nutrient bioavailability.

Phytates have both beneficial and adverse effect as any food component. Some of the adverse effects of phytates are inhibiting mineral bioavailability, inhibition of starch and protein digestibility and hamper lipid utilization. While some of the beneficial effects are: prevent radical generation, act as antidiabetic agent, and prevent from coronary heart disease and renal lithiasis. Table 3 shows the content of phytate and tannin in three types of grain amaranth. The content of phytate in raw amaranth was 360.21, 334.49 and133.55mg/100g, for white, brown and red amaranth respectively. The content of phytate in any plant food can vary depending on growing conditions such as season, soil profile, harvesting techniques, stage of maturation, species and genotype [23].

It has been reported that amaranth, being categorized under pseudocereals, had high endogenous phytase activity compared to other cereals [21]. Therefore, designing strategies to degrade the high phytate content in amaranth is indispensable. In order to optimize the conditions that activate phytases in cereals; the use of hydrothermal treatment that provides suitable condition; appears to be a promising method for maximum phytate degradation and this was observed in wheat (94.4-95.6%), rye (99.0-99.5%) and rice (99.8%) [24].

Tannis are metal chelaters such as iron and zinc and reduce their absorption [25]. The prevalence of micronutrient deficiency especially iron, zinc and calcium in developing countries whose diets are mainly plant based which are identified as poor sources of micronutrients, could be exacerbated due to the high intake of dietary thannins in those plant-based diets. Morever, tannins were also reported to complex with proteins and inhibit the action of digestive enzymes thereby reduce protein digestibility [26]. However, in the contemporary world tannins are much more friends than foe as they have diverse health benefits such as antimicrobial, antiviral, anti-inflammatory, antitumor, anticancer and antioxidative action [27-28].

Table 3 displays the content of bioactive components namely total tannins in three types of raw amaranth grain. The amount of total tannins in the brown colored amaranth was 58.36mg /100g. These values are higher than that obtained in red amaranth: 39.05mg/100g and white amaranth: 20.54mg/100g, respectively as colored substances contains high level of bioactive compounds than pale seeded once. The amount of total tannis obtained in all the three types is less than that reported by Chlopicka et al., [29] but higher than that obtained by Nsimba et al. [30] & Alvarez-Jubete et al. [31]. The content of total tannins in all the studied type of amaranth is less than that of other pseudocereals such as quinoa and buckwheat (Alvarez-Jubete et al., 2010) [31] but higher than wheat, rice and oats [32-38].

Table 3: Phytate and Tannin content of three types of raw *Amaranthus caudatus* grains.

Sample	Phytate (mg/100g)	Tannin (mg/100g)
White Amaranth	360.21	20.54
Red Amaranth	133.49	58.36
Brown Amaranth	334.55	39.05

Conclusion and Recommendations

Based on the outcomes obtained in this research and comparison with other researchers' scientific findings, the

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following conclusions and recommendations were made. All the three types of Amaranthus caudatus grains cultivated in Bench Maji Zone have been found to be rich source of protein and fat compared to most commonly consumed cereals like teff, barley, wheat, maize and rice etc. They are also a good source of iron, zinc and calcium making them a potential crop for complementing both cereals and legumes. The investigation evaluates the three types of Amaranthus caudatus Production and Nutrition Profile in Menit shasha, Menit Goldya and Maji Districts of Bench Maji Zone, South Western Ethiopia.

Red amaranth had highest mineral contents, particularly calcium and magnesium which was nearly twice those measured in the white and brown amaranth. Important minerals in the grain amaranth identified in this study included potassium (420mg/100g); calcium (173.55mg/100g); and magnesium (293.48mg/100g). Zinc and iron stabilizes immune function and reduce complications from HIV/AIDS and anemia diseases respectively; and magnesium and manganese that are crucial for infants growth and development. The content of phytate in raw amaranth was 360.21, 334.49 and133.55mg/100g, for white, brown and red amaranth respectively. Therefore, designing strategies to degrade the high phytate content in amaranth is indispensable. The amount of total tannins in the brown colored amaranth was 58.36mg/100g. These values are higher than that obtained in red amaranth: 39.05mg/100g and white amaranth: 20.54mg/100g, respectively as colored substances contains high level of bioactive compounds than pale seeded once.

Generally the macro- and micronutrient contents, mineral absorption inhibitors (phytate), fatty acid profile, bioactive compounds (tannins) were analyzed. As other scholars concluded in their findings, the balance of carbohydrates, fats, and protein allow amaranth crop the opportunity to achieve a balanced nutrient uptake with lower amounts of consumption than with other cereals. And that this could also be one of the pathways towards solving the macro - and micronutrient deficiencies experienced in Ethiopia. Consumption of grain amaranth provide nutritional and health benefits that include general improvement in well-being such as severely malnourished children recovered; and prevention and improvement of specific ailments and symptoms like people that were wasted by HIV/AIDS increased in their body mass index. Thus the proximate contents of protein, carbohydrate, fat, ash and energy showed that the grain amaranth in this investigation was full with balanced nutrients that could enhance healthy living and food security. Zinc is reported to contribute to boosting the immune system of people with AIDS and iron is required by enzymes for oxygen metabolism that reduces anemia. Multi-benefits of amaranth range from improved well-being to recovery of severely malnourished children; increased body mass index of people formerly wasted by HIV/AIDS; environmental adaptability, yield, and recipes development. The contents of the magnesium and manganese in amaranth crop are also crucial to infants' growth and development. When included in diets at both household and village levels, it could provide high protein-energy weaning foods; and enhance the nutritional status of the population toward food security and healthy living in Bench Maji Zone Ethiopia.

The nutritional limitation with the studied amaranth types was the presence of high levels of phytic acid that could potentially decrease the absorption of minerals and digestibility of starch and protein. Processing methods applied in the community, popping and fermentation may decrease the content of phytic acid but the amount left after the process may be higher than what is recommended to demonstrate minimal effect on bioavailability of iron and zinc. The content of bioactive compounds in amaranth especially total tannins are better than some common cereals like wheat, rice and oats but lower than their pseudocereal counterparts: quinoa and buckwheat. Amaranth has been used to prepare different types of foods like pasta, cake, bread, cookies, crackers etc in many countries. But due to the presence of high level of phytic acid, the use of amaranth to prepare the aforementioned foods may adversely affect mineral absorption.

I. Due to the small size of the grain, amaranth is not able to be decorticated and thus maintains micronutrients and dietary fibers concentrated in the bran. Therefore, amaranth could potentially complement both cereals and legumes to narrow down deficiencies existing in those commonly utilized cereals and legumes especially during complementary food formulation.

II. Agronomic bio fortification can provide micronutrient increases through the application of fertilizers. Therefor the amaranth crops should be provided with integrating organic and organic fertilizers for bio fortification. Which is mainly staple foods which predominate in the diets of the poor as a result the strategy could explicitly targets low income households

III. However, due to the high content of phytic acid in the studied amaranth samples, the promotion to formulate complementary food for infants and young children. The selection, fortification and breeding of other low phytic acid containing amaranth are also strongly recommended.

IV. The crop could potentially substitute other more common cereals used in complementary food formulation for young children, and thereby allowing a reduction in the proportion of legumes which generally have high anti nutritional content. In general, in Bench Maji zone, where animal source food are not easily accessed and not regularly consumed, amaranth protein could serve as a good source of essential amino acids and therefore help to enrich protein deficient or low quality protein diets for all age groups.

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V. However, estimation of the contribution amino acids to daily requirement should take into account the digestibility of the protein. This is a good attribute for individuals requiring quick energy from the meal ingested like athletes and children. The limited gastric capacity of children could only allow them to consume small amount of food. However, if the food is highly digestible, like amaranth; it helps them to satisfy their energy requirement by increasing their meal frequency.

VI. Growing of grain amaranth should be encouraged at both household and community levels to enhance the nutritional status of the populace toward food security in Bench Maji Zone.

VII. Inclusion of grain amaranth in diets should be adopted to produce high protein-energy weaning food for infants and balanced diets for adults for healthy living.

VIII. Amaranth Value Chain System that would include youths should be encouraged by Bench maji zone, Mizan Tepi University and other institutions, or Entrepreneurs in the growing, processing, value addition and marketing of grain amaranth. This would reduce youth unemployment and other associated socioeconomic problems in the Bench Maji zone.

IX. Further research studies need to be done in order to govern the status of amaranth production system, crop management practices and consumption of grain amaranth; and to promotion in a value chain system.

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