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Nutritional Diversity Assessment in Chickpea-A Prospect for Nutrient Deprived World

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Abstract
In developing countries, grain legumes are next to cereals in human food dealing with the hunger and malnutrition. Chickpea (*Cicer arietinum* L.) is the nutritious legume crop providing ample amount of proteins, nutrients and vital amino acids to human body. The aim of this mini-review is to provide an overview of the benefits of biofortification of Chickpea crop and nutritional diversity studies on Chickpea conducted so far to strengthen the biofortification process.

Key Words: Biofortification, *Cicer arietinum* (L.), Iron, Mineral micronutrients, Nutrition

Nohutta Besinsel Çeşitlilik Değerlendirmesi - Yetersiz Beslenme Sorunu Yaşayan Dünyamız Için Bir Arayış

Öz
Gelişmekte olan ülkelerde, tane baklagiller açlık ve yetersiz beslenmeyi giderme konusunda tahıllarla yan yana yer almaktadır. Nohut (*Cicer arietinum* L.) besleyici değeri yüksek bir baklagil bitkisi olup insan vücudu için yeterli miktarda protein, besin elementleri ve temel amino asitleri sağlamaktadır. Bu kısa derlemenin amacı, biyofortifikasyonu güçlendirmek için nohut bitkisinde biyofortifikasyonun yararları ve besinsel çeşitlilik konusunda günümüze kadar yapılan çalışmaları değerlendirmede genel bir bakış açısı sağlamaktır.

Anahtar Kelimeler: Biyofortifikasyon, *Cicer arietinum* (L.), Demir, Mineral mikro besin maddeleri, Beslenme

Introduction

The global population is increasing at an alarming speed and projected to go beyond nine billion by 2050 (Godfray, 2010). This rapid rise in population posed a severe threat to the food and nutritional security of human beings. Consequently, dietary intake of more than half of the human population lacks in crucial mineral elements and proteins (White and Broadley, 2009). As a result, malnutrition has evolved as a major challenge towards billions of people worldwide leading to more than 20 million deaths every year (Bouis and Welch, 2010). Not only, developing countries in Asian, African and Latin American zones are suffering from this disaster due to unequal distribution of food and limited resources (Kennedy et al., 2003; FAO, 2015); but western world including North America and Europe are also influenced by it due to dysfunctional food habits (Combs et al., 1998; Sadanandan and Channarayappa, 2014).

Although more than 22 minerals are required for the physiological development of the human body, deficiency of micronutrients has the most devastating impact on the human health affecting beyond 30% people worldwide (WHO, 2000; Welch, 2002; Welch and Graham, 2004; White and Broadley, 2005; Nestelet al., 2006; Tulchinsky, 2010; Thavarajah and Thavarajah, 2012). It has been assessed that over 3 billion people are being suffered with iron deficiency particularly women and school children (Bohra et al, 2015). Moreover, evaluations indicate that around one-third of the world population is Zinc deficient, widespread in countries with Zn deficient soils like China, India, Iran, Pakistan and Turkey (Hotz et al., 2004; Cakmak, 2008).

Besides micronutrients deficiencies, protein energy malnutrition is also a prevalent issue that needs to be addressed effectively. Although it is more prominent in children, especially of developing countries, adults are also largely afflicted by the disorder (Monti and Grillo, 1983; Haider and Haider, 1984; Duranti and Gius, 1997; World Health Organization (WHO), 2013). These nutritional deficiencies evolved due to dearth of good quality and balanced food, its expensiveness, unawareness of its nutritional value and inadequate agricultural methods based on the renovation of only major nutrients (Niba, 2003; Sadanandan and Chanaryappa, 2014). To address the evolving malnutrition across the world, several traditional approaches including supplementation and food fortification have been implemented (Welch and Graham, 2004; White and Broadly, 2005, Rana et al., 2012). However, these strategies are greatly restricted due to high consumer cost and various social and cultural constraints (White and Broadly, 2009). In such state, biofortification is considered as a potential solution to combat global malnutrition.

Biofortification

Biofortification is one of the most economical methods to develop nutrient rich crops and combat global nutrient deficiency (Welch and Graham, 2004; White and Broadley, 2005).In this process, nutrient concentration and bioavailability is increased by employing agronomic and genetic biofortification techniques. It permits the cultivation of nutrient rich varieties without declining its yield (Nestel et al., 2006). Agronomic biofortification deals with the application of fertilizer to improve the soil fertility, while genetic biofortification relies on conventional breeding and transgenic methods (Harvestplus, 2012; Hoekenga, 2014). Although majority of biofortification efforts has been made towards micronutrient and vitamins enrichment of crops, fewer studies have been conducted for protein enrichment (Welch, 1999). Agronomic biofortification requires consistent application of fertilizers making it a pricy strategy that is also hazardous to the environment (Carvalho and Vasconcelos, 2013). Biofortification through conventional breeding is a cost efficient and sustainable method as compared to agronomic biofortification, although a wide range of diversity is a prerequisite to introgressa particular character; and prolonged duration is required to develop the trait.

Biofortification by genetic engineering is a quick and competent method to improve the nutrient quality of the crops (Mayer et al., 2008). Several research studies presented that grain legumes have become a major alternative crop to fulfill the nutritional requirements of the people who are basically dependent on carbohydrate rich cereals (Graham et al., 2001). Additionally, high content of nutrients in legumes compared to cereals and their capability of nitrogen fixation make them valuable attractive crops for biofortification (Iqbal et al., 2006; White and Broadley, 2009; Bohra et al., 2015).

Chickpea- A Potential Crop for Biofortification

Chickpea is one of the most significant legume crops inherently loaded with proteins, vitamins and minerals, but still with a great prospect to enhance the nutritional value. Although it is basically grown in arid and semiarid climatic conditions, it has potential to develop in an extensive range of growth environments and support the agriculture system worldwide. Moreover, it lessens the damaging effects of farming practices on the environment by fixing the atmospheric nitrogen and refining the soil fertility (Sahin and Gecit, 2006, Caliskan et al., 2013).

It is a chief source of protein for resource-poor people mostly in developing countries that are dependent on plant proteins to fulfill their dietary needs and hence, its global demand is continuously rising. It has ample amount of oil and protein content as compared to cereals and thus, capable of supplementing the cereals based menu of a major population (Tonk et al., 2010). Carbohydrates and proteins are the major components of chickpea collectively responsible for 80% of its dry weight (Jukanti et al., 2012). An average of 4.1 mg zinc, 5 mg iron, 138 mg magnesium, 160 mg calcium and 334–446 Kcal per 100 g seeds contribute to most of the health benefits of chickpea (Petterson et al., 1997; Wood and Grusak, 2006; Jukanti et al., 2012; Ray et al., 2014). Moreover, richness of chickpea in dietary fibres, vitamins, starch, sugars, lipids and unsaturated fatty acids make it a functional food source (Chavan et al., 1989). Thus, in the growing world, biofortification of chickpea may offer great potential to alleviate malnutrition and develop sustainable agriculture.

Genetic Diversity in nutritional profile of Chickpea-An important aspect for Breeding

Assessment of genetic variability in existing chickpea gene pool for nutrient and protein content is one of the competent methods to identify potential genotypes for breeding strategy (Dwivedi et al., 2012). Although several efforts have been made to estimate the genetic variability of chickpea genotypes, still detailed studies are required to understand the adaptable range of different nutrients for genetic biofortification programs.

In 1998, Ibanez et al. estimated the genetic variability in mineral composition of 16 Desi and 21 Kabuli Chickpea cultivars grown under identical environmental agricultural conditions, hence, eliminating the genotype environment interaction effect. They obtained 1.22, 4.48, 3.53, 1.68, and 21.9 mg/100g of mean copper, iron, zinc, manganese and sodium content, respectively. In their analysis, Kabuli and Desi chickpea biotypes showed similar Zn, Fe, Cu, Mn and Nacontents. Though, Ca and Mg content in Desi biotypes were higher than Kabuli ones, K content was significantly lower. Their results were in contrast with a previous study conducted by Singh and Jambunathan, (1981) who found no difference in the mean element concentrations of eight Desi and seven Kabuli cultivars. It shows that nutrient composition not only depends on the biotypes, but also on the choice of cultivars.

Ereifej et al., 2001 evaluated the nutrient composition of three developed and one commercial Jordanian chickpea cultivars and found significant variation in protein and mineral content. They emphasized on the cumulative effect of the genotype and growing season on the measured characters. Besides seeds, ibrikci et al (2003) revealed significant variation in mineral concentrations of young leaves of 19 kabuli and desi chickpea accessions. They observed variability of 1.3-1.8 times and 1.5-2.4 times in macronutrient and micronutrient content, respectively, although there were no huge variances in leaf mineral values of kabuli and desi genotypes. Zia-Ul-Haq, (2007) determined a range of 3.5-6.0 mg per 100 g Zn and 2.4-4.1 mg per 100 g Fe in seeds of four desi chickpea cultivars. In a study, Ozer et al., 2010 examined the diversity of 91 Turkish Kabuli chickpea landraces grown under same agroclimatic conditions for several nutritional and physicochemical properties. They revealed great variation in seed protein content of landraces ranging from 17.5 to 25.3%.

Bueckert et al., 2011 screened 10 Canadian chickpea genotypes (4 kabuli and 6 desi types) for the estimation of iron, zinc, calcium and magnesium concentrations grown at two high-yielding locations in Canada in two different years. They found higher zinc, similar iron, and lesser magnesium and calcium concentrations in kabuli genotypes as compared to desi genotypes. Moreover, they estimated a positive association of calcium and iron content with phytic acid, a chickpea constituent responsible for bioavailability of nutrients. For the first time, Thavarajah and Thavarajah, 2012 reported the nutrient content and bioavailability of commercially grown USA chickpea genotypes to support the biofortification programs. They found a range of 3.7-7.4 mg/100 g Zinc, 4.6-6.7 mg/100 g Iron,0.7-1.1 mg/100 g Copper, 15.3-56.3 µg/100 g Selenium, 2627-3703 mg/kg Phosphorus, 93.4-197.4 mg/100 g Calcium, 125.1-158.7 mg/100 g Magnesium and 732.2-1125.5 mg/100 g Potassium in their study; and revealed potential mineral bioavailability of chickpea genotypes.

In 2014, Ray et al., estimated the nutrient range of eight chickpea cultivars grown at five different locations and found a great effect of year, location and cultivars on different nutrient concentrations. They found a good range of magnesium, iron, selenium, copper, manganese and zinc in chickpea seeds; however, calcium was highly dependent on the type of cultivar. Hence, they highly emphasized on increasing the calcium content by selection process so that chickpea can efficiently supply dietary calcium. Similarly, Diapari et al., 2014 found considerable variability for iron and zinc concentrations in 94 chickpea accessions (including both desi and kabuli types) grown at two different sites. Among the screened accessions, three of their kabuli and two of their desi types were loaded with both highest Fe (more than 50 ppm) and Zn (more than 40 ppm) concentrations and hence, can be directly used as potential donors in breeding programs aiming for genetic biofortification. Torutaeva et al., 2014 estimated significant variability in protein and mineral content among 23 chickpea accessions representing Kyrgyz, Turkish and Spanish cultivars along with the ICARDA breeding lines. Protein content in studied accessions was wide ranging from 14.5% to 26.9%, while concentrations for minerals were similar to those obtained by Thavarajah and Thavarajah, 2012.

Aliu et al., 2016 evaluated the chemical configuration of seven Kosovan chickpea genotypes grown in two consecutive years and revealed a wide range of variation. The mean protein, Mg, Ca, Fe and Zn content obtained in their study was 28.85 g per 100 g, 622.86 mg kg^{-1}, 347.17 mg kg^{-1}, 28.41 mg kg^{-1} and 35.54 mg kg^{-1}, respectively. In 2016, Upadhyaya et al., estimated the genetic variation for Iron and Zinc content among 92 desi and kabuli chickpea accessions grown at two varied geographical locations for two successive years. They found an average of 63.3 and 46.2 ppm of Fe and Zn, respectively. Additionally, they identified eight major QTLs participating in the regulation of chickpea seeds Fe and Zn content.

Conclusion

Most of the studies described in this short review revealed that both desi and kabuli chickpea cultivars possess sufficient amount of genetic variability for nutrient and protein content and can be effectively utilized in breeding programs. To our knowledge, none of the nutrient diversity analysis has been conducted on wild chickpea germplasm, that if conducted may provide a viable key for genetic biofortification of chickpea cultivars. Additionally, nutrients and protein rich cultivars identified in the mentioned nutrient diversity studies should be competently exploited by farmers, breeders and molecular biologists to develop enriched chickpea varieties.

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