OPEN ACCESS Freely available online

Applied Microbiology: Open Access

Review Article

Going Back to Chickpea and its Symbionts: A Review

Junjie Zhang[123*], Wenfeng Chen[4], Raghvendra Pratap Singh[5], Yimin Shang[1],

Shanshan Peng[1], Shuo Li[1], Tao Yang[6], Xuxiao Zong[6], Wenxin Chen[4]

[1]*Department of Food and Bioengineering, Zhengzhou University of Light Industry, Zhengzhou, Henan province, 450000, P. R. China*

[2]*Henan Key Laboratory of Cold Chain Food Quality and Safety Control, Henan province, 450000, P. R. China*

[3]*Collaborative Innovation Center for Food Production and Safety of Henan province, Zhengzhou 450002, Henan Province, P. R. China*

[4]*State Key Laboratory of Agrobiotechnology, Beijing 100193, China; College of Biological Sciences and Rhizobium Research Center, China Agricultural University, Beijing 100193, P. R. China*

[5]*Department of Research and Development, Biotechnology, Uttaranchal University, Dehradun-248007, India*

[6]*Institute Sciences of Crop Sciences, Chinese Academy of Agricultural, Zhongguancun South Avenue No.12, Haidian District, Beijing 100081, P. R. China*

Abstract

Chickpea, Cicer arietinum L., is an inexpensive, important, old and worldwide pulse crop consumed widely, with two distinct cultivated types of cultivar Desi and Kabuli. Chickpea is grown in over 50 countries across the Indian subcontinent, North Africa, the Middle East, southern Europe, the Americas, Australia and China. It is a good source of carbohydrates and protein, together constituting about 80% of the total dry seed mass. Chickpea consumption is reported to have several positive physiological and health benefits and might reduce the risk of chronic diseases and optimize health.

Therefore, chickpeas could potentially be considered as a 'functional food' in addition to their accepted role of providing proteins and fiber. During the past two decades, rhizobial diversity associated with chickpea has been studied extensively in several countries, in Europe, Asia, and Oceania to elaborate the impact on the sustainable qualitative and quantitative yield of chickpea. To date, Mesorhizobium ciceri, M. mediterraneum, M. muleiense and M. wenxiniae have been described to accommodate the rhizobial strains originally isolated from chickpea root nodules. In addition, several Mesorhizobium species, i.e., M. amorphae, M. loti, M. tianshanense, M. oportunistum, M. abyssinicae and M. shonense were reported as additional potential symbionts of chickpea after lateral gene transfer acquisition of symbiovar ciceri gene set. M. ciceri and M. mediterraneum are ubiquitous in most of the countries and widely studied in the Spain, Portugal, Morocco, Tunisia and India; however, none of them were found

Correspondence to: Zhang J, Department of Food and Bioengineering, Zhengzhou University of Light Industry, Zhengzhou, Henan province, 450000, P. R. China; Tel No: 86 371 8650 5810; E-Mail: kirka640@163.com

Received date: February 16, 2020; **Accepted date:** August 25, 2021; **Published date:** September 07, 2021

Citation: Zhang J (2020) Going back to chickpea and its symbionts: A review. Appli Microbiol Open Access 7: p003

M. muleiense and M. wenxiniae except in Xinjiang and Gansu Provinces Northwest China. The geographic distribution of the chickpea varieties suggested that during the introduction of chickpea from one region to another, the seeds might contain some chickpea rhizobia during the harvest or it had been inoculated with chickpea rhizobia after introduction. Chickpea rhizobial inoculation could improve the nitrogen fixation and plant growth and finally increase the yield and nutrient content of chickpea seed

Keywords: Chickpea; Cultivation; Rhizobia; Inoculation; Health; Distribution

INTRODUCTION

Primary 1 Rationale of chickpea

1.1 The origin of chickpea, types and distribution Chickpea, Cicer arietinum L., belongs to the genus Cicer, tribe Cicereae, family Fabaceae, and subfamily Papilionaceae (Singh and Diwakar 1995). It is an old world pulse and the second most important legume crop consumed worldwide (Ladizinsky 1975; Iqbal et al. 2010). The name Cicer is of Latin origin, derived from the Greek word 'kikus' meaning force or strength (Singh and Diwakar 1995). The word arietinum is also Latin, translated from the Greek 'krios', another name for both ram and chickpea (Singh and Diwakar 1995). Chickpea is also called garbanzo (Spanish), pois chiche (French), kichar or chicher (German), chana (Hindi), and gram or Bengal gram (English) (Singh and Diwakar 1995). In Turkey, Romania, Bulgaria, Afghanistan, and adjacent parts of Russia, chickpea is called 'nakhut' or 'nohut' (Vander Maesen 1987). Carbonized seeds of chickpea that have been unearthed in various archeological sites throughout the Middle East. The Middle East is also the homeland of several annual wild chickpeas, such as C. judaicum Boiss., C. pinnatifidum Jaub et Spach, and C. bijugum Rech which are apparently unrelated to the cultivated chickpea. Another two wild species of chickpea have been found in South-East Turkey, C. echinospermum Davis (DAVIS, 1969) and C. reticulatum Ladiz. (Ladizinsky 1975).

There are two distinct types of cultivar chickpea, Desi and Kabuli are widely cultivated. Morphologically, Desi (microsperma) cultivar have pink flowers, anthocyanin pigmentation on stems with a colored and thick seed coat. The kabuli (macrosperma) cultivar have white flowers, lack of anthocyanin pigmentation on stem, white or beige-colored seeds with a ram's head shape, thin seed coat and smooth seed surface (Moreno and Cubero 1978). In addition, an intermediate typewith pea-shaped seeds of local importance is recognized in India (Jukanti et al. 2012b).

The seed weight generally ranges from 0.1 to 0.3 g and 0.2 to 0.6 g in desi and kabuli types, respectively (Frimpong et al. 2010). The desi types account for about 80-85% of the total chickpea cultivated area and are mostly grown in Asia and Africa (Pande et al. 2005). The kabuli types are largely grown in West Asia, North Africa, North America and Europe (Jukanti et al. 2012b).

Chickpea is grown in over 50 countries across the Indian subcontinent, North Africa, the Middle East, southern Europe, the Americas and Australia (Jukanti et al. 2012b). Globally, it is one of the most cultivated pulses in terms of world production, with a total production of 14.2 million t and an average yield of 0.96 t ha−1 (FAO, 2014). As a cheaper source of protein, it is particularly important for low-income consumers around the world and in developing countries, where large segments of populations have limited access to food of animal origin (Ramalho Ribeiro and Portugal Melo 1990). Chickpea also cultivates well in the region where climate variability, drought and limited use of fertilizers significantly reduce productivity (Oliveira et al. 2017). India is the largest chickpea producing country, while other major chickpea producing countries include Pakistan, Turkey, Australia, Myanmar, Ethiopia, Iran, Mexico, Canada and USA (Jukanti et al. 2012b). China is another chickpea producing country from Asia, and the main planting area is Xinjiang Province, Northwest China (Zhang 98 et al. 2018b).

1.2 Nutritional Quality of Chickpea Seeds

Chickpea is a good source of carbohydrates and protein, together constituting about 80% of the total dry seed mass (Chibbar et al. 2010) in comparison to other pulses. Chickpea has been and is being consumed by humans since ancient times owing to its good nutritional properties (Jukanti et al. 2012b). It is mostly consumed as a seed food in several different forms, and preparations are determined by ethnic and regional factors (Ibrikci et al. 2003). In the Indian subcontinent, chickpea is split (cotyledons) as dhal and ground to make flour (besan) that is used to prepare different snacks (Chavan et al. 1986). In other parts of the world, especially in Asia and Africa, chickpea is used in stews, soups/salads and consumed in roasted, boiled, salted and fermented forms (Gecit 1991). These different forms of consumption provide consumers with valuable nutrition and potential health benefits (Jukanti et al. 2012b).

Classification of Carbohydrates

The total carbohydrate content in chickpea is higher than pulses (Table 2). Chickpea has: (i) monosaccharides- ribose, glucose, galactose and fructose (ii) disaccharides-sucrose, maltose and (iii) oligosaccharides- stachyose,ciceritol, raffinose and verbascose (Han and Baik 2006). The amount of these fractions varies though not significantly, between desi and kabuli genotypes (Table 1). Mono-, Di-, and Oligosaccharides Sanchez-Mata et al. (1998) reported chickpea monosaccharide concentration for galactose (0.05 g 100-g), ribose (0.11 g 100-g), fructose (0.25 g 100-g) and glucose (0.7g 100-g). Maltose (0.6%) and sucrose (1-2%) have been reported to be the most abundant free disaccharides in chickpea (Wood and Grusak 2007). α-Galactosides are the second most abundant carbohydrates in the plant kingdom after sucrose (Jones et al. 1999; Han and Baik 2006) and in chickpea they account for about 62% of total sugar (mono-, di-, and oligosaccharides) content (Sánchez-Mata et al. 1998). The two important groups of α-galactosides present in chickpea are: (i) raffinose family of oligosaccharides (RFOs) - raffinose (trisaccharide), stachyose [tetrasaccharide], and verbascose [pentasaccharide](Han and Baik 2006) and (ii) galactosyl cyclitols - including ciceritol (Table 1)(21). Ciceritol was isolated for the first time from chickpea seeds by Quemener and Brillouet(22) and later confirmed by Bernabé et al.(1993). Ciceritol and stachyose, two important galactosides in chickpea constitutes 36-43% and 25% respectively of total sugars (mono-, di-, and oligosaccharides) in chickpea seed (Sánchez-Mata et al. 1998; Aguilera et al. 2009b). Chickpea has lower values for absolute flatulent α-galactosides [1.56 g 100-g] compared to other pulses like white beans [2.46 g 100-g], lentils [2.44 g 100-g] and pinto beans [2.30 g 100-g] (Sánchez-Mata et al. 1998).

Polysaccharides

Polysaccharides are high molecular weight monosaccharide polymers present as storage carbohydrate (e.g. starch) or as structural carbohydrates (e.g. cellulose) providing structural support (Wood and Grusak 2007). Among the storage polysaccharides, chickpea is reported to synthesize and store starch and not galactomannans (Wood and Grusak 2007). Starch is the major carbon storage reserve in pulse seeds (Chibbar et al. 2010). Starch is made up of two large glucan polymers, amylose and amylopectin, in which the glucose residues are linked by α-(1→4) bonds to form a linear molecule and the linear molecule is branched by α-(1→6) linkages (Chibbar et al. 2010). The amylopectin side chains are packed into different polymorphic forms in the lamellae of the starch grains: ‘A’ type in cereals and ‘C’ type in pulses. The ‘C’ polymorph is considered to be of intermediate type between ‘A’ polymorph in cereals and ‘B’ polymorph in tubers in packing density and structure (Chibbar et al. 2010). The content of starch varies from 41-50% of the total carbohydrates (Jambunathan and Singh 1980; Dalgetty and Baik 2003; Özer et al. 2010), with kabuli types having more soluble sugars (sucrose, glucose and fructose) compared to the desi types (Jambunathan and Singh 1980). The total starch content of chickpea seeds is reported to be ˜ 525 g kg-1 dry matter, about 35% of total starch is considered to be resistant starch (RS) and the remaining 65% as available starch (Aguilera et al. 2009a; Aguilera et al. 2009b). Chickpea seeds have higher amylose content [30-40%] than 25% in wheat (Williams and Singh 1987; Guillon and Champ 2002). The in vitro starch digestibility values (ISDV) of chickpea vary from 37-60% (Khalil et al. 2007; Zia-Ul-Haq et al. 2007), and are higher than other pulses like black grams, lentils and kidney beans (Rehman and Shah 2005).

Dietary Fiber

Dietary fiber (DF) is the indigestible part of plant food in the human small intestine.The dietary fibers can be classified into soluble and insoluble. Total dietary fiber content (DFC) in chickpea is 18-22 g 100-g of raw chickpea seed (Aguilera et al. 2009b; Tosh and Yada 2010) and it has higher amount of DF among pulses (Table 2). Soluble and insoluble DFC is about 4-8 and 10-18 g 100-g of raw chickpea seed respectively (Rincón et al. 1998; Dalgetty and Baik 2003). The fiber content of chickpea hulls on a dry weight basis is lower [75%] compared to lentils [87%] and peas [89%] (Dalgetty and Baik 2003). The desi types have higher total DFC and insoluble DFC compared to the kabuli types. This could be due to thicker hulls and seed coat in desi (11.5 % of total seed weight) compared to the kabuli types (only 4.3-4.4 % of total seed weight) (Rincón et al. 1998). Further, Wood et al. (2011) have reported that the thinner seed coat in kabuli types is due to thinner palisade and parenchyma layers with fewer polysaccharides.

PROTEIN CONTENT

Among the different pulses, chickpea is reported to have higher protein bioavailability (Sánchez-Vioque et al. 1999; Yust et al. 2003). The protein content in chickpea significantly varies as percentage of the total dry seed mass before (17-22%) and after (25.3-28.9%) dehulling (Hulse 1991; Badshah et al. 2003). The differences in crude protein concentration of kabuli [K] and desi [D] types are inconsistent sometimes showing significant differences [241 g kg-1 in ‘K’ vs 217 g kg-1 in ‘D’] (Singh and Jambunathan 1981) but not always [217 g kg-1 in ‘K’ vs 215 g kg-1 in ‘D’] (Rincón et al. 1998). Chickpea protein quality is better than some pulse crops such as black gram [Vigna mungo L.], green gram [Vigna radiata L.] and red gram [Cajanuscajan L.] (Kaur et al. 2005).

Amino Acid Profile

Chickpea contains the known 18 kinds of amino acids (Wang and Daun 2004; Alajaji and El-Adawy 2006; Wang et al. 2010) though the sulfur-rich amino acids (methionine and cystine) are limiting in pulses (Table 3). There are no significant differences in the amino acid profiles of kabuli and desi type chickpea (Wang and Daun 2004; Wang et al. 2010).

Fat Content and Fatty Acid Profile

Total fat content in raw chickpea seeds varies from 2.70-6.48 % (51,58). Fat content of 3.40-8.83% and 2.90-7.42% in kabuli and desi type chickpea seeds respectively was reported by Wood and Grusak (Wood and Grusak 2007). The fat content in chickpea (6.04 g 100-g) is higher than the other pulses like lentil (1.06 g 100-g), red kidney bean (1.06 g 100-g), mungbean (1.15 g 100-g) and pigeonpea (1.64 g 100-g) and also cereals like wheat (1.70 g 100-g) and rice (˜0.60 g 100-g) (USDA National Nutrient Database for Standard Reference, Release 22 (2009).http://www.nal.usda.gov/fnic/foodcomp/search/).

Chickpea is composed of polyunsaturated fatty acids (PUFA; ˜ 66%), monounsaturated fatty acids (˜19%) and ˜ 15% saturated fatty acids (Table 4). On average, oleic acid was higher in the kabuli types and linoleic acid was higher in the desi types (Table 4). Chickpea is relatively a good source of nutritionally important PUFA, linoleic acid (51.2 %; LA) and monounsaturated oleic acid (32.6%; OA). Chickpea has higher amounts of linoleic and oleic acid compared to other edible pulses like lentils (44.4% LA; 20.9 OA), pea (45.6 LA; 23.2 OA) and bean 46.7% LA; 28.1% OA) (Wang and Daun 2004).

Linoleic acid is the dominant fatty acid in chickpea followed by oleic and palmitic acids (Table 4).

Minerals and Vitamins

Chickpea, like other pulses, not only brings variety to the cereal-based daily diet of millions of people in Asia and Africa, but also provides essential vitamins and minerals (Duhan et al. 1998; Cabrera et al. 2003). Raw chickpea seed (100 g) on average provides about 5.0 mg 100-g of iron, 4.1 mg 100-g of zinc, 138 mg 100-g of magnesium and 160 mg 100-g of calcium. About 100 g of chickpea seed can meet daily dietary requirements of iron (1.05 mg/day in males and 1.46 mg/day in females) and zinc (4.2 mg/day and 3.0 mg/day) and 200 g can meet that of magnesium (260 mg/day and 220 mg/day) (FAO 2002). There were no significant differences between the kabuli and desi genotypes except for calcium, with desi types having a higher content than kabuli types (Quinteros et al. 2001; Wang and Daun 2004). Selenium, a nutritionally important essential trace element is also found in chickpea seed [8.2 μg 100-g] (USDA National Nutrient Database for Standard Reference, Release 22 (2009). http://www.nal.usda.gov/fnic/foodcomp/search/) (Cabrera et al. 2003). Chickpea is reported to have other trace elements including aluminum [10.2 μg /g], chromium [0.12 μg/g], nickel [0.26 μg/g], lead [0.48 μg/g], and cadmium [0.01 μg/g] (Guillon and Champ 2002). Chickpea is a relatively inexpensive and good source of folic acid and tocopherols [both γ and α; Table 8] (CıFtcı̇ et al. 2010). It is a relatively good source of folic acid coupled with more modest amounts of water soluble vitamins like riboflavin (B2), panthothenic acid (B5) and pyridoxine (B6), and these levels are similar or higher than that observed in other pulses [Table 9](ska and Szefer 2006).

REFERENCES

1. Aguilera, Y., Esteban, R.M. and Benitez, V. (2009a) Starch, Functional Properties, and Microstructural
2. Characteristics in Chickpea and Lentil As Affected by Thermal Processing. J Agric Food Chem 57,10682-10688.
3. Aguilera, Y., Martín-Cabrejas, M.A., Benítez, V., Mollá, E., López-Andréu, F.J. and Esteban, R.M. (2009b)
4. Changes in carbohydrate fraction during dehydration process of common legumes. Journal of Food Composition & Analysis 22, 678-683.
5. Ahmed, R., Anthony, B., David, T., Sarah, B., Judy, F., Tina, B., Behjat, K.H., Zhongyi, L., Sadequr, R. and Matthew, M. (2006) High-amylose wheat generated by RNA interference improves indices of large-bowel health in rats. Proceedings of the National Academy of Sciences of the United States of America 103, 3546-3551.
6. Alajaji, S.A. and El-Adawy, T.A. (2006) Nutritional composition of chickpea (Cicer arietinum L.) as affected by microwave cooking and other traditional cooking methods. Journal of Food Composition & Analysis 19, 806-812.
7. Alexandre, A., Brigido, C., Laranjo, M., Rodrigues, S. and Oliveira, S. (2009) Survey of Chickpea Rhizobia diversity in Portugal reveals the predominance of species distinct from Mesorhizobium ciceri and Mesorhizobium mediterraneum. Microbial Ecology 58, 930-941.
8. Anonymous (2014) Handbook of Agriculture. In Indian Council of Agricultural Research. New Delhi. Aurand, L., Woods, A. and Wells, M. (1987) Food composition and analysis. New York: Van Nostrand Reinhold Company.
9. Badshah, A., Khan, M., Bibi, N. and al., e. (2003) Quality studies of newly evolved chickpea cultivars. Advances in Food Sciences 25, 95-99.
10. Bernabe, M., Fenwick, R., Frias, J., Jimenezbarbero, J., Price, K., Valverde, S. and Vidalvalverde, C. (1993) Determination, by NMR spectroscopy, of the structure of ciceritol, a pseudotrisaccharide isolated from lentils. Journal of Agricultural & Food Chemistry 41, 870-872.
11. Cabrera, C., Lloris, F., Giménez, R., Olalla, M. and López, M.C. (2003) Mineral content in legumes and nuts: contribution to the Spanish dietary intake. Science of the Total Environment 308, 1-14.
12. Chavan, J.K., Kadam, S.S. and Salunkhe, D.K. (1986) Biochemistry and technology of chickpea (Cicerarietinum L.) seeds. C R C Critical Reviews in Food Technology 25, 107-158.
13. Chibbar, R.N., Ambigaipalan, P. and Hoover, R. (2010) Molecular diversity in pulse seed starch and complex carbohydrates and its role in human nutrition and health. Cereal Chemistry 87, 342-352.Asian Journal of Chemistry 22.
14. Crujeiras, A.B., Dolores, P., Itziar, A. and J Alfredo, M. (2007) A hypocaloric diet enriched in legumesspecifically mitigates lipid peroxidation in obese subjects. Free Radic Res 41, 498-506.
15. Cummings, J., Stephen, A. and Branch, W. Implications of dietary fibre breakdown in the human colon.
16. In Banbury Report 7 Gastrointestinal Cancer eds. Bruce, W., Correa, P., Lipkin, M., Tannenbaum, S. and
17. Wilkins, T. pp.71-81. New York: Cold Spring Harbor Laboratory Press.
18. Dalgetty, D. and Baik, B. (2003) Isolation and characterization of cotyledon fibres from peas, lentils and chickpea. Cereal Chemistry 80, 310-315.
19. Das, S., Pareek, N., Raverkar, K., Chandra, R. and Kaustav, A. (2012) Effectiveness of micronutrient
20. application and Rhizobium inoculation on growth and yield of chickpea. Int J Agric Env Biotech 5,445-452.
21. Duhan, A., Khetarpaul, N. and Bishnoi, S. (1998) Improvement in starch digestibility (in vitro) of various Pigeonpea cultivars through processing and cooking. Ecology of Food & Nutrition 37, 557-568.
22. Duranti, M. (2006) Grain legume proteins and nutraceutical properties. Fitoterapia 77, 67-82.
23. Elias, N.V. and Herridge, D.F. (2015) Naturalised populations of mesorhizobia in chickpea (Cicerarietinum L.) cropping soils: effects on nodule occupancy and productivity of commercial chickpea.Plant and Soil 387, 233-249.
24. Elkoca, E., Kantar, F. and Sahin, F. (2008) Influence of Nitrogen Fixing and Phosphorus SolubilizingBacteria on the Nodulation, Plant Growth, and Yield of Chickpea. Journal of Plant Nutrition 31,157-171.
25. Erman, M., Demir, S., Ocak, E., Tüfenkçi, Ş., Oğuz, F. and Akköprü, A. (2011) Effects of Rhizobium,arbuscular mycorrhiza and whey applications on some properties in chickpea (Cicer arietinum L.) under irrigated and rainfed conditions 1—Yield, yield components, nodulation and AMF colonization.Field Crops Research 122, 14-24.
26. Fernando, W., Hill, J., Zello, G. and al., e. (2010) Diets supplemented with chickpea or its mainoligosaccharide component raffinose modify faecal microbial composition in healthy adults. BeneficialMicrobes 1, 197-207.
27. Frimpong, A., Sinha, A., Tar'An, B., Warkentin, T.D., Gossen, B.D. and Chibbar, R.N. (2010) Genotypeand growing environment influence chickpea (Cicer arietinum L.) seed

composition. Journal of theScience of Food & Agriculture 89, 2052-2063.

28. Gecit, H. (1991) Chickpea utilization in Turkey. In Proceedings of a Consultants Meeting. pp.69-74. AP,India: ICRISAT.
29. Giovannucci, E., ., Ascherio, A., ., Rimm, E.B., Stampfer, M.J., Colditz, G.A. and Willett, W.C. (1995)
30. Intake of carotenoids and retinol in relation to risk of prostate cancer. J Natl Cancer Inst 87, 1767-1776.
31. Giri, N. and Joshi, N. (2010) Growth and yield response of chick pea (Cicer arietinum) to seedinoculation with Rhizobium sp. Nature Science 8, 232-236.
32. Glick, B.R. (2012) Plant growth-promoting bacteria: mechanisms and applications.Scientifica,2012,(2012-10-11) 2012, 963401.
33. Gopalakrishnan, S., Sathya, A., Vijayabharathi, R., Varshney, R.K., Gowda, C.L.L. and Krishnamurthy, L.(2015) Plant growth promoting rhizobia: challenges and opportunities. Biotech 5, 355-377.
34. Guillon, F. and Champ, M.M. (2002) Carbohydrate fractions of legumes: uses in human nutrition andpotential for health. British Journal of Nutrition 88, 293-306.
35. Han, I. and Baik, B.-K. (2006) Oligosaccharide content and composition of legumes and their reductionby soaking, cooking, ultrasound and high hydrostatic pressure. Cereal Chemistry 83, 428-433.
36. Hulse, J. (1991) Nature, composition and utilization of pulses. In Uses of Tropical Grain Legumes,
37. Proceedings of a Consultants Meeting. pp.11-27. AP, India: ICRISAT.
38. Ibrikci, H., Knewtson, S.J. and Grusak, M.A. (2003) Chickpea leaves as a vegetable green for humans:evaluation of mineral composition. Journal of the Science of Food & Agriculture 83, 945-950.
39. Iqbal, A., Ateeq, N., Khalil, I.A., Perveen, S. and Saleemullah, S. (2010) Physicochemical characteristicsand amino acid profile of chickpea cultivars grown in Pakistan. Journal of Foodservice 17, 94-101.
40. Jambunathan, R. and Singh, U. (1980) Studies on desi and kabuli chickpea (Cicer arietinum L.) cultivars. Chemical composition. In Proceedings of the International Workshop on Chickpea Improvement.pp.61-66. AP, India: ICRISAT.
41. James, S.L., Muir, J.G., Curtis, S.L. and Gibson, P.R. (2010) Dietary fibre: a roughage guide. InternalMedicine Journal 33, 291-296.
42. Jenkins, D.J.A., Kendall, C.W.C., Augustin, L.S.A. and Vuksan, V. (2002) High–complex carbohydrate orlente carbohydrate foods? American Journal of Medicine 113, 30-37.
43. Jones, D., DuPont, M. and Ambrose, M. (1999) The discovery of compositional variation for theraffinose family of oligosaccharides in pea seeds. Seed Sci Res 9, 305-310.
44. Jukanti, A.K., Gaur, P.M., Gowda, C.L. and Chibbar, R.N. (2012a) Nutritional quality and health benefitsof chickpea (Cicer arietinum L.): a review. British Journal of Nutrition 108 Suppl 1, S11-26.
45. Jukanti, A.K., Gaur, P.M., Gowda, C.L. and Chibbar, R.N. (2012b) Nutritional quality and health benefitsof chickpea (Cicer arietinum L.): a review. Br J Nutr 108 Suppl 1, S11.
46. Julio, G.C., Javier, V., María, D.M.Y., Justo, P., Manuel, A. and Francisco, M. (2004) Effect of chickpeaaqueous extracts, organic extracts, and protein concentrates on cell proliferation. Journal of Medicinal Food 7, 122-129.
47. Kaur, M., Singh, N. and Sodhi, N.S. (2005) Physicochemical, cooking, textural and roastingcharacteristics of chickpea (Cicer arietinum L.) cultivars. Journal of Food Engineering 69, 511-517.
48. Kaur, N., Sharma, P. and Sharma, S. (2015) Co-inoculation of Mesorhizobium sp. and plant growtpromoting rhizobacteria Pseudomonas sp. as bio-enhancer and bio-fertilizer in chickpea (Cicerarietinum L.). Legume Research 38.
49. Kendall, C.W., Emam, A., Augustin, L.S. and Jenkins, D.J. (2004) Resistant starches and health. Journalof Aoac International 87, -.
50. Khalil, A.W., Zeb, A., Mahmood, F., Tariq, S., Khattak, A.B. and Shah, H. (2007) Comparison of sproutquality characteristics of desi and kabuli type chickpea cultivars (Cicer arietinum L.). LWT - FoodScience and Technology 40, 937-945.
51. Ladizinsky, G. (1975) A new Cicer from Turkey. In Notes from the royal botanic garden. pp.201-202.Edinburgh.
52. Laranjo, M., Machado, J., Young, J.P. and Oliveira, S. (2004) High diversity of chickpea Mesorhizobiumspecies isolated in a Portuguese agricultural region. FEMS Microbiology Ecology 48, 101-107.
53. Mathers, J.C. (2002) Pulses and carcinogenesis: potential for the prevention of colon, breast and other cancers. British Journal of Nutrition 88, 273-279.
54. Messina, M.J. (1999) Legumes and soybeans: overview of their nutritional profiles and health effects.American Journal of Clinical Nutrition 70, 439S.
55. Mittala, G., Brar, A.P.S. and Soni, G. (2009) Protective role of chickpea seed coat fibre onnitrosodiethylamine-induced toxicity in hypercholesterolemic rats. Experimental & ToxicologicPathology 61, 363-370.
56. Moinuddin, D., TA, Hussain, S., Khan, M., Hashmi, N., Idrees, M., Naeem, M. and A., A. (2014) Use of Nand P biofertilizers together with phosphorus fertilizer improves growth and physiological attributes ofchickpea. Global J Agri Agric Sci 2, 168-174.
57. Moreno, M.T. and Cubero, J.I. (1978) Variation in Cicer arietinum L. Euphytica 27, 465-485.
58. Muir, J.G. and O'Dea, K., . (1992) Measurement of resistant starch: factors affecting the amount ofstarch escaping digestion in vitro. American Journal of Clinical Nutrition 56, 123-127.
59. Murillo, G., Choi, J.K., Pan, O., Constantinou, A.I. and Mehta, R.G. (2004) Efficacy of garbanzo and 601 soybean flour in suppression of aberrant crypt foci in the colons of CF-1 mice. Anticancer Research 24, 602 3049.
60. Murty, C.M., Pittaway, J.K. and Ball, M.J. (2010) Chickpea supplementation in an Australian diet affects food choice, satiety and bowel health. Appetite 54, 282-288.
61. Nour, S.M., Cleyet-Marel, J.C., Normand, P. and Fernandez, M.P. (1995) Genomic heterogeneity of strains nodulating chickpeas (Cicer arietinum L.) and description of Rhizobium mediterraneum sp. nov. International Journal of Systematic Bacteriology 45, 640-648.
62. Nour, S.M., Fernandez, M.P., Normand, P. and Cleyet-Marel, J.C. (1994) Rhizobium ciceri sp. nov., consisting of strains that nodulate chickpeas (Cicer arietinum L.). International Journal of Systematic 610 Bacteriology 44, 511-522.
63. Oliveira, R.S., Carvalho, P., Marques, G., Ferreira, L., Nunes, M., Rocha, I., Ma, Y., Carvalho, M.F., 612 Vosátka, M. and Freitas, H. (2017) Increased protein content of chickpea (Cicer arietinum L.) 613 inoculated with arbuscular mycorrhizal fungi and nitrogen-fixing bacteria under water deficit conditions. Journal of the Science of Food & Agriculture 97.
64. Osorio-Díaz, P., Agama-Acevedo, E., Mendoza-Vinalay, M. and al., e. (2008) Pasta added with chickpea flour: chemical composition,

in vitro starch digestibility and predicted glycemic index. Cienc Tecnol Aliment 6, 6-12.

65. Özer, S., Karaköy, T., Toklu, F., Baloch, F.S., Kilian, B. and Özkan, H. (2010) Nutritional and 619 physicochemical variation in Turkish kabuli chickpea (Cicer arietinum L.) landraces. Euphytica 175, 237-249.

66. Pande, S., Siddique, K.H.M., Kishore, G.K., Bayaa, B., Gaur, P.M., Gowda, C.L.L., Bretag, T.W. and Crouch, J.H. (2005) Ascochyta blight of chickpea (Cicer arietinum L.): a review of biology, pathogenicity, and disease management. Australian Journal of Agricultural Research 56, 317-332.

67. Paul, N., Marja, C. and Andriana, C. (2004) Effects of long-term consumption and single meals of 625 chickpeas on plasma glucose, insulin, and triacylglycerol concentrations. American Journal of Clinical Nutrition 79, 390-395.

68. Pittaway, J.K., Ahuja, K.D.K., Robertson, I.K. and Ball, M.J. (2007) Effects of a controlled diet 628 supplemented with chickpeas on serum lipids, glucose tolerance, satiety and bowel function. Journal of the American College of Nutrition 26, 334-340.

69. Pugalenthi, M., Vadivel, V., Gurumoorthi, P. and al, e. (2004) Comparative nutritional evaluation of little known legumes, Tamarindus indica, Erythrina indica and Sesbania bispinosa. Tropical and Subtropical Agroecosystems 4, 107-123.

70. Quinteros, A., Farré, R. and Lagarda, M.J. (2001) Optimization of iron speciation (soluble, ferrous andferric) in beans, chickpeas and lentils. Food Chemistry 75, 365-370.

71. Raicht, R.F., Cohen, B.I., Fazzini, E.P., Sarwal, A.N. and Takahashi, M., . (1980) Protective effect of plantterols against chemically induced colon tumors in rats. Cancer Research 40, 403-405.

72. Ramalho Ribeiro, J. and Portugal Melo, I. (1990) Composition and nutritive value of chickpea. In 638 Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries eds. Saxena, M., Cubero, J. and Wery, J. pp.107-111. Zaragoza: CIHEAM.

73. Rehman, Z.U. and Shah, W.H. (2005) Thermal heat processing effects on antinutrients, protein andstarch digestibility of food legumes. Food Chemistry 91, 327-331.

74. Rincón, F., Martínez, B. and Ibáñez, M. (1998) Proximate composition and antinutritive substances inchickpea (Cicer arietinum L.) as affected by the biotype factor. J Sci Food Agric 78, 382-388.

75. Rudresh, D.L., Shivaprakash, M.K. and Prasad, R.D. (2005) Effect of combined application of Rhizobium, phosphate solubilizing bacterium and Trichoderma spp. on growth, nutrient uptake and yield of 646 chickpea (Cicer aritenium L.). Applied Soil Ecology 28, 139-146.

76. Sánchez-Mata, M.C., Peñuela-Teruel, M.J., Cámara-Hurtado, M., Díez-Marqués, C. and Torija-Isasa, M.E. (1998) Determination of Mono-, Di-, and Oligosaccharides in Legumes by High-Performance Liquid Chromatography Using an Amino-Bonded Silica Column. Journal of Agricultural & Food Chemistry 46, 650 3648-3652.

77. Sánchez-Vioque, R., Clemente, A., Vioque, J., Bautista, J. and Millán, F. (1999) Protein isolates from chickpea (Cicer arietinum L.): chemical composition, functional properties and protein characterization. Food Chemistry 64, 237-243.

78. Sahai, P. and Chandra, R. (2011) Performance of Liquid and Carrier-based Inoculants of Mesorhizobium ciceri and PGPR (Pseudomonas diminuta) in Chickpea (Cicer arietinum L.) on Nodulation, Yield and Soil properties. Journal of the Indian Society of Soil Science 59, 263-267.

79. Sanders, T., Oakley, F., Miller, G. and al., e. (1997) Influence of n-6 versus n-3 polyunsaturated PUFAs in diets low in saturated PUFAs on plasma lipoproteins and hemostatic factors. Arterioscler Thromb Vasc Biol 17, 3449-3460.

80. Shahzad, S.M., Khalid, A., Arif, M.S., Riaz, M., Ashraf, M., Iqbal, Z. and Yasmeen, T. (2014) 661 Co-inoculation integrated with P-enriched compost improved nodulation and growth of Chickpea 662 (Cicer arietinum L.) under irrigated and rainfed farming systems. Biology & Fertility of Soils 50, 1-12.

81. Singh, F. and Diwakar, B. eds. (1995) Chickpea Botany and Production Practices. . Patancheru 502 324 Andhra Pradesh, India.

82. Singh, G., Sekhon, H.S. and Sharma, P. (2011) Effect of irrigation and biofertilizer on water use, 666 nodulation, growth and yield of chickpea (Cicer arietinum L.). Archives of Agronomy & Soil Science 57, 667 715-726.

83. Singh, S., Bawa, S.S., Singh, S., Sharma, S.C. and Sheoran, P. (2015) Productivity, profitability and 669 sustainability of rain-fed chickpea under inorganic and biofertilization in foothills of north-west Himalayas. Archives of Agronomy & Soil Science 61, 1151-1163.

84. Singh, U. and Jambunathan, R. (1981) Studies on desi and kabuli chickpea (Cicer arietinum L.) cultivars: levels of protease inhibitors, levels of polyphenolic compounds and in vitro protein digestibility. Journal of Food Science 46, 1364-1367.

85. Singh, Z. and Singh, G. (2018) Role of Rhizobium in chickpea (Cicer arietinum) production-A review. ska, A.L. and Szefer, P. (2006) Vitamins B in grain and cereal-grain food, soy-products and seeds. Food Chemistry 95, 116-122.

86. Solaiman, A., Talukder, M.S. and Rabbani, M.G. (2011) Influence of Some Rhizobium Strains on Chickpea: Nodulation, dry matter yield and Nitrogen uptake. Bangladesh Journal of Microbiology 27. Sridevi, M. and Mallaiah, K.V. (2009) Phosphate solubilization by Rhizobium strains. Indian Journal of Microbiology 49, 98.

87. Tagore, G., Namdeo, S. and Shah, S. (2014) Effect of microbial inoculants on nutrient uptake, yield and quality of chickpea genotypes. Int J Agric Sci and Vet Med 2, 19-23.

88. Tena, W., Wolde-Meskel, E., Degefu, T. and Walley, F. (2017) Genetic and phenotypic diversity of rhizobia nodulating Chickpea (Cicer arietinum L.) in soils from southern and central Ethiopia. Canadian Journal of Microbiology 63, 690-707.

89. Tharanathan, R.N. and Mahadevamma, S. (2012) Grain legumes—a boon to human nutrition. Trendsin Food Science & Technology 14, 507-518.

90. Tosh, S.M. and Yada, S. (2010) Dietary fibres in pulse seeds and fractions: Characterization, functionalattributes, and applications. Food Research International 43, 450-460.

91. Unkovich, M., Herridge, D., Peoples, M., Cadisch, G., Boddey, B., Giller, K., Alves, B. and Chalk, P. (2008) Measuring Plant-Associated Nitrogen Fixation in Agricultural Systems. In Australian Centre for International Agricultural Research. p.16. Canberra.

92. Van der Maesen, L.J.G. (1987) Origin, history and taxonomy of chickpea. In The chickpea ed. Saxena,

93. M.C.a.S., K.B., eds. pp.11-34. Wallingford, Oxon, UK: CAB International.

94. Verma, A., Rawat, A.K. and More, N. (2014) Extent of Nitrate and Nitrite Pollution in Ground Water ofRural Areas of Lucknow, U.P., India. Current World Environment 9, 114-122.

95. Verma, J.P., Yadav, J., Tiwari, K.N. and Kumar, A. (2013) Effect of indigenous Mesorhizobium spp. and plant growth promoting rhizobacteria on yields and nutrients uptake of chickpea (Cicer

arietinum L.) under sustainable agriculture. Ecological Engineering 51, 282-286.

96. Wang, N. and Daun, J. (2004) The Chemical Composition and Nutritive Value of Canadian Pulses.Canadian Grain Commission Report, 19-29.

97. Wang, X., Gao, W., Zhang, J., Hua, Z., Li, J., He, X. and Hao, M. (2010) Subunit, amino acid composition and in vitro digestibility of protein isolates from Chinese kabuli and desi chickpea (Cicer arietinum L.) cultivars. Food Research International 43, 567-572.

98. Williams, P. and Singh, U. (1987) Nutritional quality and the evaluation of quality in breeding programs.

99. In The Chickpea eds. Saxena, M. and Singh, K. pp.329-356. Wallingford, UK: CAB International.

100. Wood, J. and Grusak, M. (2007) Nutritional value of chickpea. In Chickpea breeding and management eds. Yadav, S., Redden, R., Chen, W. and Sharma, B. pp.101-142. Wallingford, UK: CAB International.

101. Wood, J., Knights, E. and Choct, M. (2011) Morphology of chickpea seeds (Cicer arietinum L.):Comparison of desi and kabuli types. Int J Plant Sci 172, 632-643.

102. Yadav, J. and Verma, J.P. (2014) Effect of seed inoculation with indigenous Rhizobium and plant growth promoting rhizobacteria on nutrients uptake and yields of chickpea (Cicer arietinum L.). European Journal of Soil Biology 63, 70-77.

103. Ying, Y., Libin, Z., Yuanjun, G., Yibo, Z., Jingfeng, T., Fengying, L., Wenbin, S., Boren, J., Xiaohua, Y. and Mingdao, C. (2007) Dietary chickpeas reverse visceral adiposity, dyslipidaemia and insulin resistance in 716 rats induced by a chronic high-fat diet. British Journal of Nutrition 98, 720-726.

104. Yust, M.A.M., Pedroche, J., Girón-Calle, J., Alaiz, M., Millán, F. and Vioque, J. (2003) Production of aceinhibitory peptides by digestion of chickpea legumin with alcalase. Food Chemistry 81, 363-369.

105. Zhang, J., Guo, C., Chen, W., De, L.P., Zhang, Z., Shang, Y. and Wang, E.T. (2018a) Mesorhizobium 720 wenxiniae sp. nov., isolated from chickpea (Cicer arietinum L.) in China. Int J Syst Evol Microbiol, 1930-1936.

106. Zhang, J.J., Guo, C., Chen, W.F., Shang, Y.M., de Lajudie, P., Yang, X., Mao, P.H., Zheng, J.Q. and Wang, E.T. (2018b) Dynamic succession of chickpea rhizobia over years and sampling sites in Xinjiang, China. Plant Soil 425, 241-251.

107. Zhang, J.J., Liu, T.Y., Chen, W.F., Wang, E.T., Sui, X.H., Zhang, X.X., Li, Y., Li, Y. and Chen, W.X. (2012a)

108. Mesorhizobium muleiense sp. nov., nodulating with Cicer arietinum L. International Journal ofSystematic and Evolutionary Microbiology 62, 2737-2742.

109. Zhang, J.J., Lou, K., Jin, X., Mao, P.H., Wang, E.T., Tian, C.F., Sui, X.H., Chen, W.F. and Chen, W.X. (2012b)Distinctive Mesorhizobium populations associated with Cicer arietinum L. in alkaline soils of Xinjiang,China. Plant Soil 353, 123-134.

110. Zhang, J.J., Yang, X., Guo, C., de Lajudie, P., Singh, R.P., Wang, E.T. and Chen, W.F. (2017)

111. Mesorhizobium muleiense and Mesorhizobium gsp. nov. are symbionts of Cicer arietinum L. in alkaline 733 soils of Gansu, Northwest China. Plant Soil 410, 103-112.

112. Zia-Ul-Haq, M., Iqbal, S., Ahmad, S., Imran, M., Niaz, A. and Bhanger, M.I. (2007) Nutritional and compositional study of Desi chickpea (Cicer arietinum L.) cultivars grown in Punjab, Pakistan. Food Chemistry 105, 1357-1363.