Role of pigeon pea (Cajanus cajan L.) in human nutrition and health: A review

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ABSTRACT

Legumes and cereals are good, relatively inexpensive, sources of proteins and energy for third world countries, including India. India is a major pulse producing country, sharing 36 and 28% of total area and production of these crops. Pigeon pea (Cajanus cajan L.) is widely consumed in the form of dhal as an economical source of protein. It is a dense source of nutrients, but its nutritional elements are masked by some anti-nutritional factors decreased by different processing methods. The non-nutritive compounds of pigeon pea have been investigated for their role in the enhancement of the antioxidant and anti-carcinogenic effects. Recent evidences suggest that pigeon pea bioactive compounds play a vital role in modulating the gut microbiota hence, can reduce inflammation. The Prebiotic potential of non-digestible raffinose family oligosaccharides has also been investigated in animal models. Research on pigeon pea prebiotic oligosaccharide and health benefits is scanty and some research regarding this novel approach remains inconclusive and there is still much to be studied. This review article focuses on the nutritional, anti-nutritional factors bioactive compounds and other health benefits of pigeon pea.

Key words: Anti-nutrients, Oligosaccharides, Pigeon pea, Prebiotics.

Abbreviations

IYP International year of pulses
RFO Raffinose family oligosaccharides
PUFA Poly unsaturated fatty acids
RDI Recommended daily intake
HDL High density lipoprotein
LDL Low density lipoprotein
NHANES National Health and Nutrition Examination Survey
LPO Lipid peroxidation
CSA Cajaninstillbene acid
TNF-α Tumor necrosis factor alpha
IL-1β Interleukin 1 beta
SCD Sickle cell disease
AIN American Institute of Nutrition
LPO Lipid Peroxidation

Food legumes are of major importance in the human diet contributing as the major source of vegetable protein. Nowadays, pulses are gaining much interest in the area of functional foods. The 68th UN General Assembly announced 2016 as the International Year of Pulses (IYP). The IYP 2016 aims at public awareness of the nutritional benefits of pulses and towards the food security and nutrition (International Year of Pulses 2016).

India ranks high in the production of pulses. Pigeon pea, chickpea, black gram, green gram, lentils and peas are major pulses consumed. Among legumes, pigeon pea is predominantly grown and consumed in India. It is also known as red gram, arhar, tur dal belonging to the family of Leguminosae. Pigeon pea was long considered to be one of the two species of the genus Cajanus DC. The cultivation of the pigeon pea dates back to at least 3,500 years and is assumed that eastern part of peninsular India is the center of origin (Van der Maeson 1995).

Pigeon pea is accepted in many parts of the world since it is very much resistant to drought (ICRISAT). Pigeon pea seeds compliment cereals such as corn, maize, wheat and rice. It forms a good portion of the human diet in many African, Asian and South American countries as well. Pigeon pea is the economical source of protein, carbohydrate, minerals and vitamins such as B-complex particularly in the vegetarian diet. Along with the cereals pigeon pea provide well balanced diet and can be comparable to other dense protein sources like whey and soy (Akporhonor et al. 2006).

Besides its nutritional value, pigeon pea also possesses various medicinal properties due to the presence of a number of polyphenols and flavonoids (Singh 2016). The nutritional components of pigeon pea are considered crucial for human nutrition, and it is evident from several studies that consumption of pigeon pea is associated with a lower risk of several diseases (Singh and Basu 2012).

In India, red gram is mostly consumed in the form of dhal (decorticated split cotyledons), after cooking in water, to the desirable degree of softness and immature green seeds are used as vegetable. Nowadays pigeon pea is incorporated into food products like biscuits, noodles, pasta, sausages as a novel ingredient for nutritional purposes, owing to its high fibre and protein content, gluten-free status, low glycemic
index, antioxidant levels, as well as functional properties like fat absorption and water binding capacity (Keshav 2015).

Till date several authors have reviewed the nutritional quality and health benefits of pigeon pea in relation to its bioactive compounds. This narrative review article is aimed at reviewing the recent advances in research carried out till date for the purposes of evaluation of nutritional quality and health benefits of newly cultivated pigeon pea including its novel prebiotic potential. The updated findings on the effect of pigeon pea consumption in animals and human health are summarized.

**Nutritional composition of pigeon pea**

**Proximate composition:** The proximate compositions such as moisture, protein, fat, carbohydrate, ash and dietary fiber of pigeon pea is shown in Table 1 (Oke 2014., Eltayeb et al. 2010., Olalekan and Bosede 2010., Adamu and Oyetunde 2013., Kunyanga et al. 2013). The pigeon pea seed is made up of 85% cotyledon, 14% seed coat, and about 1% embryo. It is a rich source of protein, carbohydrates, minerals and vitamins. It’s protein content ranges between 20-22% CHO between 51.4 – 58.8%, Crude fibre between 1.2 – 8.1% and lipid between 0.6 – 3.8% (Faris 1990).

**Carbohydrates:** The starch and non-starch are the major constituents of carbohydrates of pigeon pea consisting of significant amount of α-galactosides. Different carbohydrate fractions of pigeon pea are (i) available carbohydrates which are digested in the small intestine and (ii) unavailable carbohydrates like oligosaccharides, resistant starch, non-cellulosic polysaccharides, pectins, hemicelluloses, and cellulose, which are not digested in the small intestine (Cummings 2007).

The available and unavailable carbohydrate content of pigeon pea is summarized in Table 2 (Jairo et al. 1991., Mulimani and Devindra 1998., Apata 2008., Devindra et al. 2012). The unavailable carbohydrates of pigeon pea like fructans and raffinose family oligosaccharides (RFOs) are the major water soluble carbohydrates which adversely affect bioavailability of certain vital nutrients.

**Glycemic carbohydrate:** Carbohydrates which provide glucose for metabolism is referred to as ‘glycaemic carbohydrate’, whereas carbohydrates that reaches the large intestine prior to being metabolized, are called as ‘nonglycaemic carbohydrate’. Most of the available carbohydrates, some oligosaccharides and rapidly digested starches may be classified as a glycaemic carbohydrate (Cummings 2007).

In a study cooked legumes including pigeon pea, chickpea, black gram, mung bean and white bean were tested for blood glucose response among healthy human subjects. The glycemic response to pigeon pea was 30.99 (Panlasigui 2009). Recently Devindra et al. (2016) have reported the lower glycemic index of pigeon pea among the commonly consumed legumes tested.

**Amino acid profile:** Generally the sulphur containing amino acids (methionine and cystine) are limiting in pulses. The amino acid profile of pigeon peas is summarized in Table 3.
Pigeon pea seeds contain high amounts of lysine, leucine, aspartic acid, glutamic acid and arginine and provide essential amino acids when consumed with cereals and other sulphur containing amino acids (Ade-Omowaye et al. 2015). In a study Pigeon pea can replace soybean without adversely affecting the performance of rabbits (Adamu and Oyetunde 2013).

**Fatty Acid Profile:** The major saturated fatty acid in pigeon pea is the palmitic acid which constitutes 15-25% in the neutral lipids, 20-40% in the glycolipids, and 26-30% in the phospholipids. The fatty acid profile of pigeon pea is summarized in Table 4. A study was conducted to know the nutritional potential of nine underexploited legumes in Southwest Nigeria. The most abundant polyunsaturated fatty acid (PUFA) identified in pigeon pea was linoleic acid (C18:2) (Ade-Omowaye et al., 2015).

Caprylic, lauric, oleic and eicosanoic acids were present only in small quantities. The resistant starch derived from processed red gram showed a higher amount of short chain fatty acids. Whereas Indian food composition tables reported the palmitic acid content of pigeon pea as 236 ± 11.0, oleic acid was 78.55± 6.71, stearic acid was 40.95± 3.31 mg/100g respectively (Longvah et al. 2017).

**Vitamin and mineral content:** Pigeon pea is a good source of water soluble vitamins, like thiamine, riboflavin, niacin etc. Vitamin content of pigeon pea is summarized in Table 5. Pigeon pea was reported to be the richest vegetable for Vitamin C with 569 mg/100g. Its content was three times higher than for peppers and could cover more than 949% of the recommended daily intake (RDI) of Vitamin C and pigeon pea is the palmitic acid which constitutes 15-25% in the neutral lipids, 20-40% in the glycolipids, and 26-30% in the phospholipids. The fatty acid profile of pigeon pea is summarized in Table 4. A study was conducted to know the nutritional potential of nine underexploited legumes in Southwest Nigeria. The most abundant polyunsaturated fatty acid (PUFA) identified in pigeon pea was linoleic acid (C18:2) (Ade-Omowaye et al., 2015).

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Pigeon pea is a good source of minerals such as phosphorus, magnesium, iron, calcium, sulphur and potassium but low in sodium (Kunyanga et al. 2013). Mineral content of pigeon pea is summarized in Table 6. Sangle, (2015) have reported minerals constituents of two viable mutant varieties of pigeon pea. Mean content of nitrogen ranged from 1.95% - 3.33% and 2.24% - 3.17%, calcium content ranged from 0.25% - 0.37% and 0.26% - 0.51% and phosphorus content of viable mutants ranged from 0.56 % - 0.72 % and 0.58% - 0.80% in varieties of pigeon pea respectively (Sangle, 2015). Whereas Indian food composition tables reported the calcium content of pigeon pea as 1.39, copper 1.32, iron 5.37 mg/100g respectively (Longvah et al. 2017).

**Anti-nutritional factors:** Like other legume seeds Pigeon pea seeds also contain some anti-nutritional factors including phytolectins, polyphenols (phenols and tannins) and enzyme inhibitors (trypsin, chymotrypsin, and amylase). Different anti-nutritional factors of pigeon pea are summarized in Table 7 (Harris et al. 2014., Nwaogu and Emejulu 2010., Nwosu et al. 2013., Balogun 2013., Aja et al. 2015a). These anti-nutritional factors can be reduced by different processing methods like chemical soaking (Devindra and Aruna 2016). Germination was found to be the best method for decreasing the phytic acid content of pigeon pea. Application of gamma irradiation can be used as an effective method of preservation of pigeon pea flour and their products (Bamidele and Akanbi 2013).

Table 3: Amino acid profiles of pigeon pea.

| Amino acid    | Akande et al.,(2010) (g/16gN) | Nwokolo,(1987) (g/100g) | Kunyanga et al., (2013) (g/100g) | Ade-Omowaye et al. (2015) (g/kg) |
|---------------|-------------------------------|------------------------|---------------------------------|---------------------------------|
| Lysine        | 7.79                          | 7.4                    | 0.25-                            | 14.77                           |
| Histidine     | 3.66                          | 5.0                    | 0.66                            | 7.93                            |
| Arginine      | 5.86                          | 6.9                    | 1.11                            | 13.51                           |
| Aspartic acid | 11.56                         | 9.9                    | 1.84                            | 22.55                           |
| Threonine     | 3.12                          | 3.7                    | 0.72                            | 8.25                            |
| Serine        | 3.59                          | 4.9                    | 0.99                            | 1.42                            |
| Ghtamic acid  | 9.23                          | 19.7                   | 3.14                            | 43.31                           |
| Proline       | 3.17                          | 4.8                    | 0.85                            | 1.44                            |
| Glycine       | 3.07                          | 4.2                    | 0.69                            | 7.85                            |
| Alanine       | 3.79                          | 4.6                    | 0.91                            | 9.72                            |
| Cystine       | 1.19                          | 0.8                    | 0.24                            | 5.47                            |
| Valine        | 5.85                          | 4.4                    | 1.05                            | 8.67                            |
| Methionine    | 1.19                          | 1.1                    | 0.23                            | 2.65                            |
| Isoleucine    | 3.47                          | 3.7                    | 0.64                            | 7.71                            |
| Leucine       | 6.78                          | 7.8                    | 1.38                            | 16.48                           |
| Tyrosine      | 2.63                          | 2.9                    | 0.47                            | 5.52                            |
| Phenylalanine | 6.15                          | 8.9                    | 1.69                            | 22.19                           |
| Tryptophan    | ND                            | —                      | 0.15                            | —                               |
Phenolics such as p-coumaric acid or vanillic acid were also detected in pigeon pea. The phytochemical analysis of leaf seed and stem extracts of pigeon pea showed the presence of saponins, tannins, alkaloids flavonoids, anthraquinones and reducing sugars (Harris et al. 2014), but, cardiac glycosides and terpenoids were absent in some of the components of pigeon pea. Pigeon pea is a good source of alkaloids (Aja et al. 2015). The results also revealed that anthocyanins were found to be present in the leaf and seed of pigeon pea and the leaves contain more of the bioactive compounds than the seeds suggesting the use of different parts of pigeon pea plant on various diseases (Ade-Omowaye et al. 2015).

**Health benefits:** The nutritional components of pigeon pea are widely considered crucial for human nutrition, because of phytochemicals, bioactive compounds which play vital roles in humans. Traditionally *Cajanus cajan* leaves have been used by Rabha tribe to cure jaundice and also described as useful for the treatment of smallpox, chicken pox, measles and also as an astringent, mouthwash by local people of North East India (Sarma et al. 2015).

Pigeon pea can be a source of remedy in the control of sickle cell anaemia. In India, many Sickle cell disease (SCD) patients are using pigeon pea for effective management of erythrocytes sickling in Chhattisgarh (Verma 2015). In an ethnomedical survey pigeon pea plant was

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**Table 4:** Fatty acid profile of pigeon pea (g/kg).

| Fatty acid          | Nwokolo, (1987) (g/100g) | Kanyunga et al. (2013) (g/100g) | Ade –Omovaye et al. (2015) (g/kg) | Longvah et al. (2017) (mg/100g) |
|---------------------|--------------------------|---------------------------------|----------------------------------|---------------------------------|
| Capric acid (10:0)  | 2.45                     | —                               | —                                | —                               |
| Lauric acid (12:0)  | 18.56                    | —                               | —                                | —                               |
| Myristic acid (14:0)| 23.73                    | —                               | —                                | —                               |
| Palmitic acid (16:0)| 10.98                    | 26.2±0.00                       | 21.59                            | 236.00±11.0                     |
| Stearic acid (18:0) | 3.32                     | 4.0±0.01                        | 5.88                             | 40.95±3.31                      |
| Oleic acid (18:1)   | 8.44                     | 9.2±0.01                        | 10.21                            | 78.55±6.71                      |
| Linoleic acid (18:2)| 22.54                    | 53.7±0.19                       | 49.69                            | —                               |
| α-Linolenic acid (18:3)| —                      | 4.7±0.44                        | —                                | —                               |
| Arachidic acid      | —                        | —                               | 1.26                             | —                               |
| Lignoceric acid     | —                        | —                               | —                                | —                               |
| % TSFA              | —                        | —                               | 32.63                            | —                               |
| %MUFA              | —                        | —                               | 67.37                            | —                               |
| %PUFA              | —                        | —                               | 10.61                            | —                               |
| %MUFA              | —                        | —                               | 56.49                            | —                               |

**Table 5:** Vitamin content of pigeon pea (mg/100g).

| Vitamins         | Longvah et al., (2017) (mg/100g) | Faris et al., (1987) (mg/g) | Kanyunga et al., (2013) (mg/g) | Singh et al., (2016) (mg/g) |
|------------------|----------------------------------|-----------------------------|--------------------------------|----------------------------|
| B-Carotene       | —                                | —                           | 0.05±0.03                       | 0.6                        |
| Thiamin (V-B1)   | 0.74±0.028                       | 0.40                        | 0.72±0.08                       | 0.18                       |
| Riboflavin (V-B2)| 0.15±0.015                       | 0.17                        | 0.14±0.33                       | 2.9                        |
| Niacin           | 2.42±0.18                        | 2.20                        | 2.90±0.10                       | —                         |
| Ascorbic acid (V-C)| —                   | NA                           | 4.80±0.00                       | —                         |
| Pantothenic acid | 1.56±0.13                        | 0.68                        | —                               | 1.26                       |
| Pyridoxine       | —                                | 0.07                        | —                               | 0.28                       |
| Tocopherol (γ+α) | —                                | 0.39                        | —                               | —                         |
| Folic acid * (µg/100g) | 173                  | 100.00                      | 456                             | —                         |
| Total folate     | 229±19.0                         | —                           | —                               | —                         |

**Table 6:** Mineral composition of pigeon pea.

| Minerals          | Longvah et al. (mg/100g) | Olaleken & Bosede (2017) (mg/g) | Nwokolo (1987) (2010) (mg/kg) | Kanyunga et al., (2013) (mg/100g) |
|-------------------|--------------------------|---------------------------------|-------------------------------|----------------------------------|
| Calcium           | 1.39±11.8                | 0.65±0.03                       | 1500                          | 80.50±1.22                      |
| Magnesium         | —                        | 1.55±0.01                      | 1410                          | 108.00±0.02                     |
| Copper            | 1.32±0.15                | 0.56±0.03                      | —                             | 18                              |
| Iron              | 5.37±1.36                | 0.36±0.03                      | 39                            | 5.60±1.41                       |
| Zinc              | 2.3                      | 1.54±0.10                      | 24                            | 2.70±0.00                       |
| Sodium            | —                        | —                              | 24                            | 0.33±0.00                       |
| Phosphorus        | —                        | 55.00±0.20                     | 2450                          | 334.00±0.00                     |
| Potassium         | —                        | —                              | 12500                         | —                               |
recorded as traditional medicinal plant used in Northern and South-Eastern Côte d’Ivoire for the treatment of anaemia (Kone 2011). Pigeon pea also has anti-ulcer potential (Mansoor 2015).

The European Society of Hypertension recommended diet and lifestyle approaches as a basis for prevention and treatment of hypertension. From animal model, it was both water extracts of pigeon pea and water extracts of B. subtilis fermented pigeon pea improved systolic blood pressure and diastolic blood pressure in spontaneously hypertensive rats (Lee et al. 2015).

**Use as functional foods:** A study was conducted to investigate the survival of Lactobacillus reuteri ATCC 55730 in cream with 40% pigeon pea and 20% oat. The study concluded that L. reuteri ATCC 55730 had the highest viability in cream with 40% pigeon pea and 20% oat (Barboza et al. 2013). The effect of the use of pigeon pea as a substrate in the production of a legume-based fermented product with Lactobacillus acidophilus ATCC 314 or Lactobacillus casei ATCC 393 was studied by Parra et al. Pigeon pea-based fermented probiotic product was suitable for both the strains (Parra et al. 2013).

In a study, the effects of a dietary prebiotic, inulin and probiotic was investigated in mice using cellulose-based AIN-93G diets under conditions allowed for the growth of commensal bacteria (Kuo et al. 2013).

**Prebiotic potential:** A prebiotic is defined as a selectively fermented ingredient that allows specific changes, both in the composition and/or activity in the gastrointestinal microflora that confers benefits upon host well-being and health (Roberfroid et al. 2010). Fermentation of dietary carbohydrates provides the energy for the growth and activity of the intestinal microbiota.

Several studies established the role of prebiotics in weight control, by improving microbial balance, ameliorating adiposity and increasing mucosal integrity with decreased inflammation (John et al. 2012). A number of mechanisms have been implicated in the link between intestinal microbiota, increased fatty acid metabolism, and storage of calories as fat (Mallappa et al. 2012). The prebiotics can be a tool to modulate gut microbiota which plays a role in the pathophysiology of obesity.

A diet rich in non-digestible carbohydrates induced significant weight loss and concomitant structural changes of the gut microbiota in simple obese children (Zhang et al. 2015). In another study consumption of prebiotics for 16 weeks significantly improved bifidobacterial abundance in overweight and obese children and proved that prebiotic fiber is a potential treatment option to reduce body fat by gut microbiota modulation (Nicolucci et al. 2015).

Recently Devinda et al. (2017) have demonstrated the prebiotic potential of red gram raffinose oligosaccharides in an animal model. The results of the prebiotic potential of red gram oligosaccharides have shown a hypolipidemic effect and lowered blood glucose level, improved HDL and decreased LDL. This new array of research may provide enough evidence for the prebiotic potential of pigeon pea.

**Antioxidant potential:** The bioactive compounds of pigeon pea seeds contain some defense machinery. Four important compounds, pinoresinol, cajainstilbene acid (CSA), vitexin and orientin isolated from ethanolic extracts of pigeon pea found to possess significant antioxidant activities (Pal et al. 2011).

Antioxidant potential of pigeon pea seed husk was investigated and results revealed a potent anti-oxidant activity (Rani et al. 2014). The aqueous extract of the pigeon pea had the highest antioxidant activity possibly because of the presence of polyphenols (Mahitha et al. 2015). Uchegbu and Ishipu (2015) studied antioxidant activity of extract of germinated pigeon pea in alloxan-induced diabetic rats. Consumption of germinated pigeon pea extract resulted in reduction of fasting blood glucose level and LPO in diabetic rats (Uchegbu and Ishipu 2015).

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**Table 7:** Anti-nutritional factors in pigeon pea (g/100g).

| Constituents       | Nwaogu & Emejulu, (2010) (mg/100g) | Nwosu et al., (2013) (g/100g) | Balogun, (2013) (mg/100g) | Harris, (2014) (g/100g) | Aja, (2013) (mg/100g) |
|--------------------|-----------------------------------|-------------------------------|--------------------------|--------------------------|-----------------------|
| Alkaloids          | —                                 | 0.323                         | —                        | 2.65±0.01                | 385.54±75.15          |
| Phenol             | —                                 | 0.160                         | —                        | 3.82±0.15                | —                     |
| Flavono            | —                                 | —                             | —                        | 2.11±0.03                | 31.08±8.20            |
| Saponin            | 5.10±0.20                         | 0.466                         | 1.19                     | 6.35±0.96                | 1.82±0.29             |
| Tannin             | 0.10±0.01                         | 0.220                         | 1.05                     | 0.23±0.01                | 17.30±0.47            |
| Hydrogen cyanide   | —                                 | —                             | —                        | —                        | —                     |
| Phytate            | 11.57±1.20                        | 7.180**                       | 0.65                     | —                        | —                     |
| Oxalate            | 28.58±1.02                        | 1.017                         | 1.81                     | —                        | —                     |
| Trypsin inhibitor  | —                                 | 0.139                         | 0.14                     | —                        | —                     |
| Cyanogenic glycoside | —                                | —                             | —                        | —                        | —                     |
| Glycosides         | —                                 | —                             | —                        | —                        | —                     |
| Anthocyanin        | —                                 | —                             | —                        | —                        | —                     |

*TIU/100g, ** mg/100g
Hypcholesterolemic effect: The consumption of pulses and legumes has been reported to ameliorate serum cholesterol levels and increase the saturation levels of cholesterol in the bile. Pigeon pea is a good source of saponins which have been implicated for the control of high cholesterol level and they bind to the bile salts (Aja et al. 2015).

Overweight and obesity: The diet high in whole grains is associated with the lower body mass index, smaller waist circumference, reduced risk of overweight and obesity (Butt et al. 2011). Pigeon pea has high protein content and this dietary protein may promote weight loss by inducing satiety hence decrease energy expenditure. Using data from the National Health and Nutrition Examination Survey (NHANES), it was observed that adults who consumed a variety of legumes had significantly lower body weights compared with those who did not consume legumes (Polak 2015).

Role in diabetes (Hypoglycemia): It is acknowledged that certain fibre rich foods like whole pulses can affect glycemic control in diabetes and hyperlipidemia. Pigeon pea is the most effective hypoglycemic medicinal plant commonly studied in relation to diabetes and their complications and owing to its varied degree of hypoglycemic activity. In a study substitution of red meat with legumes improved lipid profiles and glycemic control among diabetes patients (Hosseinipour-Niazi 2015).

In another study, there was a reduction in glucose levels of rats treated with ethanol extract of pigeon pea leaves and an increase in ALT, AST and ALP levels when compared with those treated with Moringa oleifera extract (Aja et al. 2015b). In a study, crude methanol extract of pigeon pea seed husks mitigated starch-induced postprandial glycemic excursions and reduced glycemic load in rats similar to the standard drug acarbose (Tiwari et al. 2013). The hypoglycemic effect of crackers produced from sprouted pigeon pea caused hypoglycemic effect in diabetic rats and led to a reduction of measured biochemical indices (Uchehgu 2016).

Cancer prevention: Alkaloids of pigeon pea have been implicated for inducing a stress response and apoptosis in human breast cancer cell. DNA fragmentation was observed in human breast cancer cells treated with cajanol, a novel anti-cancer agent from pigeon pea roots (Luo et al. 2010). The methanol extract of the plant has been shown to demonstrate cytotoxicity against three cancer cell lines, namely human breast adenocarcinoma cell line MCF-7, human large cell lung carcinoma cell line COR-L23 and human amelanotic melanoma C32 (Ashidi et al. 2010).

Anti-inflammatory: In another study, the ethanol extracts of pigeon pea and cyanidin-3-monoglucoside suppressed the production of inflammatory cytokines, including TNF-α, IL-1β, and IL-6 (Lai et al., 2012). Hence, pigeon pea leaves can be developed as an effective herbal remedy for the treatment and prevention of inflammation or associated ailments (Patel and Bhutani 2014).

In a recent study, the pigeon pea extract inhibited carrageenan-induced inflammation by 85 and 95%, respectively. This was accompanied by a decrease of TNF-α and IL-6, as well as significant decrease in IgG serum levels (Hassan et al. 2015).

Antimicrobial effect: Pigeon pea plant extract is inhibitory to some bacterial pathogens (Braga et al. 2007). The leaf part of pigeon pea is an excellent source of natural antimicrobial substances. Moreover, cajanustatine is a potential anti-bacterial agent against Gram-positive microorganism (Kong et al. 2010). The presence of tannins, flavonoids and alkaloids in pigeon pea extract has clinically relevant antifungal activity (Brito et al. 2012).

A study investigated the protective effect of cajainstilbene acid against corticosterone induced injury in PC12 cells and examined the potential mechanisms for the same (Jiang et al. 2014). Different extracts of leaf, seed and root of the pigeon pea were proven to be a great potential source of antibacterial compounds (Devi et al. 2016) and also aid in wound healing activity. In a study, wound healing activity of hydrogel obtained from pigeon pea seed husk was carried out in albino rats. Gel formulation showed significant antibacterial activity against both gram positive and gram negative selected bacteria and the percentage wound closure and epithelialization for the gel formulation treated group was comparable with those of standard group treated with Band aid (Patil and Mastiholimath 2011).

Hepatoprotective: Pigeon pea is already known for its hepatoprotective function. Pigeon pea plant protein extracts can up-regulate and counteract the inflammatory process, minimize the damage to the liver, delay disease progression, and reduce its complications in liver (Rizk et al. 2014) and kidneys (Aly et al. 2016). The pigeon pea extract was potential towards antioxidative protection against iron-overload-induced liver damage in mice and improved hepatic antioxidants (Sarkar et al. 2013).

Pigeon pea plant extract also had promising anthelmintic effects against F. hepatica (Alvarez et al. 2015) and a poly herbal formulation from pigeon pea could protect the liver cells from CC34 - induced liver damages (Arka et al. 2015).

In another study hepatoprotective activity of pigeon pea was studied in sodium fluoride treated Swiss albino (BALB/C) mice. Treatment with extract of pigeon pea exhibited significant anti-oxidant and hepatoprotective activity (Kayathri et al. 2015).

CONCLUSION
Pigeon pea is among the essential pulse in arid and semiarid tropical areas of the world. It is a dense source of nutrients and plays a promising role in human nutrition. Pigeon pea in view of their nutrient profile seems to be ideal for inclusion in designing snack foods, baby and sports foods. Various parts of pigeon pea have already been utilized for therapeutic use since ages.
From this review, it was noted that pigeon pea is a good source of antioxidants and can prevent the oxidative stress related disorders like cancer and cardio vascular diseases. Consumption of pigeon pea has several health benefits due to the presence of bioactive compounds and helps in the weight management, alleviating cholesterolemia and diabetes hence can be a remedy to metabolic syndrome as well.

The hepatoprotective potential of pigeon pea is promising since it has a vital role in the control of liver damage. The past decade has seen several new trends in the field of application of pigeon pea in nutraceutical industry. Pigeon pea can also be an alternative to artificial nutrition formulas which induce a low grade inflammation. Hopefully, research will soon offer enough data to show the efficacy of pigeon pea in gut health by possible biochemical alterations.

Further research is in need to understand the role of pigeon pea prebiotics to prevent or control diabetes, obesity, cardiovascular diseases, irritable bowel syndrome and other health benefits and understand the underlying mechanisms that could greatly contribute to disease prevention strategies in humans.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

REFERENCES

Adamu AS and Oyetunde JG (2013) Comparison of dietary proximate and mineral values of two varieties of bean. Asian J Natu Appl Sci 2: 103-106.

Ade-Omowaye BIO, Tucker GA, and Smetanska I (2015) Nutritional potential of nine underexploited legumes in South west Nigeria. Int Food Res J 22:798-806.

Aja PM, Alhum EU, Ezereani NN, Nwali BU, Edwin N (2015a) Comparative Phytochemical Composition of Cajanus cajan Leaf and Seed. Int J Mic Res 6: 42-46.

Aja PM, Igwenyi IO, Ugwu Okechukwu PC, Orji OU, Alhum EU (2015b) Evaluation of Anti-diabetic effect and liver function indices of ethanol extracts of moringa oleifera and cajan cajan leaves in alloxan induced diabetic albino rats. Global Veterinaria 14: 439-447.

Akande KE, Abubakar MM, Adegbola TA, Bogoro SE, Doma UD (2010) Chemical evaluation of the nutritive quality of pigeon pea (Cajanus cajan (L). Millsp.). Int J Poultry Sci 9: 63-65.

Akporheren EE, Egwikaide PA, Eguavoen IO (2006) Effect of Sprouting on in vitro digestibility of some locally consumed leguminous seeds. J Appl Sci Env Man 10: 55-58.

Alvarez-Mercado JM, Ibarra-Velarde F, Alonso-Diaz MA, Vera-Montenegro Y, Avila-Acevedo JG, Garcia-Bores AM (2015) In vitro antihelmintic effect of fifteen tropical plant extracts on excysted flukes of Fasciola hepatica. BMC Vet Res 11(45) 1-6.

Aly HF, Rizk MZ, Abo-Elmatty DM, Desoky MM, Ibrahim NA, Younis EA (2016) Therapeutic and protective effects of Caesalpinia longisili and Cajanus cajan proteins against acetaminophen overdose-induced renal damage. Toxicol Ind Health 32: 753-68.

Apat A (2008) Effect of cooking methods on available and unavailable carbohydrates of some tropical grain legumes. Afr J Biote 7: 2940-2945.

Arka G, Anindita K, Ankit S, Kumar SA, Kumar MS (2015) Preliminary evaluation of hepatoprotective potential of the polyherbal formulation. J Internt Ethno 11: 104:

Ashidi JS, Houghton PJ, Hylands PJ, Effert T (2010) Ethnobotanical survey and cytotoxicity testing of plants of South-western Nigeria used to treat cancer, with isolation of cytotoxic constituents from Cajanus cajan Millsp. leaves. J Ethnophar 128: 501-12.

Balogun BI (2013) Comparative evaluation of nutritive value of pigeon pea (Cajanus cajan (L).Millsp.) and cowpea (Vignaunguiculata (L.) Walp). J VocTech Edu 10: 109-121.

Bamidele OP and Akanbi CT (2013) Influence of gamma irradiation on the nutritional and functional properties of pigeon pea (Cajanus cajan) flour. Afr J Food Sci 7: 285-290.

Barboza Y, Márquez E, Parra K, Piñero MP, Medina LM. (2012) Development of a potential functional food prepared with pigeon pea (Cajanus cajan), oats and Lactobacillus reuteri ATCC 55730. Int J Food Sci Nut 63: 813-20.

Braga FG, Bouzada MLM, Fabri RL, de O Matos M, Moreira FO, Scio E, Coimbra ES (2007) Antileishmanial and antifungal activity of plants used in traditional medicine in Brazil. J Ethno Phar 111: 396–402.

Brito SA, Rodrigues FFG, Campos AR and da Costa JGM (2012) Evaluation of the antifungal activity and modulation between Cajanus cajan (L). Millsp. leaves and roots ethanolic extracts and conventional antifungals. Pharr Magazine 8: 103-6.

Butt MS, Shahzadi N, Suleria H, Sultan T, Imran Chohan M (2011) Effect of dietary fiber in lowering serum glucose and body weight in sprague dawley rats. Func Foods Health Disease 1: 261-278.

Cummings JH and Stephen AM (2007) Carbohydrate terminology and classification. Eur J Clin Nut 61: S5-18.

Devi RR, Premalatha R, Saranya A (2016) Comparative analysis of phytochemical constituents and antibacterial activity of leaf, seed and root extract of Cajanus cajan (L). Millsp. Int J Cur Mic Appl Sci 5: 485–494.

Devindra S and Aruna T (2016) Effect of Chemical Soaking, Toasting and Crude â-Galactosidase Enzyme Treatment on the Oligosaccharide Content of Red Gram Flour. J Food Proc Pres doi: 10.1111/jfpp.12922.

Devindra S, Aruna T, Hemalatha R and Mohammed S (2017) Hypolipidemic effect of red gram (Cajanus cajan L.) prebiotic oligosaccharides in Wistar NIN Rats. J Diet Suppl. DOI: 10.1080/19390211.2017.1350246.
Devindra S, Shilpa C, Charu K, Aruna T, Prasad GBKS (2016). Estimation of glycermic carbohydrate and glycermic index / load of commonly consumed cereals, legumes and mixture of cereals and legumes. Int J Diab Deve Coun doi:10.1007/s13410-016-0526-1.

Devindra S, Sreenivas RJ, Bhaskar V, Mulimani VH (2012) Effect of heat treatment on á-galactoside content of red gram seeds (Cajanus cajan, L.). J Food Proc Pres 36: 97-103.

Ellong EN, Billard C, Adene S, Rochefort K (2015) Polyphenols, carotenoids, vitamin C content in tropical fruits and vegetables and impact of processing methods. Food Nut Sci 6: 299-313.

Eltayeb ARSM, Ali AO, Haron R (2010) The chemical composition of pigeon pea (Cajanus cajan) seed and functional properties of extracts of in tropical fruits and vegetables and in rabbits. J Food Biochem 3: 60270.

Hassan EM, Matloub AA, Aboutaleb ME, Ibrahim NA, Mohamed SM (2015) Assessment of anti-inflammatory, anti-nociceptive, munnomodulatory, and antioxidant activity of Cajanus cajan L. seeds cultivated in Egypt and its phytochemical composition. Phyto Biol 9: 1-12.

Kothari N, Kalaimathi RV, Karthick Rajan D and Sivamani P (2015) Hepatoprotective activity of Cajanus cajan in sodium fluoride treated swiss albino (balb/c) mice. World J Pharm Sci 4:1805-1814.

Keshav KB (2015) Optimization of High Fiber Bun Formula and its Nutritional Evaluation. Int J Human Nut Diet 3: 89-93.

Kong Yu, Yu-Jie Fu, Yuan-Gang Gu, Fang-Rong Chang, Yung-Husan Chen, Xiao-Lei Liu, Johannes Stelten, Hans-Martin Schiebel (2010) Cajanuslactone, a new coumarin with anti-bacterial activity from pigeon pea (Cajanus cajan (L.) Millsp.) leaves. Food Chem 121: 1150-1155.

Kunyanga C, Imungi J and Vellingiri V (2013) Nutritional evaluation of indigenous foods with potential food-based solution to alleviate hunger and malnutrition in Kenya. J App Biosci 67: 5277-5288.

Kuo SM, Merhige PM and Hagey LR (2013) The effect of dietary prebiotics and probiotics on body weight, large intestine indices, and fecal bile acid profile in wild type and IL10-/- mice. PLoS One, 8: e60270.

Lai YS, Hsu WH, Huang JJ and Wu SC (2012) Antioxidant and anti-inflammatory effects of pigeon pea (Cajanus cajan L.) extracts on hydrogen peroxide- and lipopolysaccharide-treated RAW264.7 macrophages. Food Function 3: 1294–301.

Lee BH, Lai YS, Wu SC (2015) Antioxidation, angiotensin converting enzyme inhibition activity, natto kinase, and anti-hypertension of Bacillus subtilis (natto)-fermented pigeon pea. Int J Clin Nutr 4: 127-134.

Longvah T, Ananthan R, Bhaskara Chary K and Venkaiah K (2017) Indian food composition tables. ICMR, New Delhi, India.

Luo M, Liu YM, Le L, Li ZY, Si JY, Liu XM, Chang Q, Pan RL (2014) Cajaninstilbene acid prevents corticosterone-induced apoptosis in PC12 cells by inhibiting the mitochondrial apoptotic pathway. Cell Phys Biochem 34: 1015-26.

John K, Di Baise, Daniel N, Frank and Ruchi Mathur (2012) Impact of the gut microbiota on the development of obesity: Current Concepts. American Journal of Gast Supp 1: 22-27.

Kang Y, Yu-Jie Fu, Yuan-Gang Gu, Fang-Rong Chang, Yung-Husan Chen, Xiao-Lei Liu, Johannes Stelten, Hans-Martin Schiebel (2010) Cajanuslactone, a new coumarin with anti-bacterial activity from pigeon pea (Cajanus cajan (L.) Millsp.) leaves. Food Chem 121: 1150-1155.

Kunyanga C, Imungi J and Vellingiri V (2013) Nutritional evaluation of indigenous foods with potential food-based solution to alleviate hunger and malnutrition in Kenya. J App Biosci 67: 5277-5288.

Kuo SM, Merhige PM and Hagey LR (2013) The effect of dietary prebiotics and probiotics on body weight, large intestine indices, and fecal bile acid profile in wild type and IL10-/- mice. PLoS One, 8: e60270.

Lai YS, Hsu WH, Huang JJ and Wu SC (2012) Antioxidant and anti-inflammatory effects of pigeon pea (Cajanus cajan L.) extracts on hydrogen peroxide- and lipopolysaccharide-treated RAW264.7 macrophages. Food Function 3: 1294–301.

Lee BH, Lai YS, Wu SC (2015) Antioxidation, angiotensin converting enzyme inhibition activity, natto kinase, and anti-hypertension of Bacillus subtilis (natto)-fermented pigeon pea. Int J Clin Nutr 4: 127-134.

Longvah T, Ananthan R, Bhaskara Chary K and Venkaiah K (2017) Indian food composition tables. ICMR, New Delhi, India.

Luo M, Liu YM, Le L, Li ZY, Si JY, Liu XM, Chang Q, Pan RL (2014) Cajaninstilbene acid prevents corticosterone-induced apoptosis in PC12 cells by inhibiting the mitochondrial apoptotic pathway. Cell Phys Biochem 34: 1015-26.

John K, Di Baise, Daniel N, Frank and Ruchi Mathur (2012) Impact of the gut microbiota on the development of obesity: Current Concepts. American Journal of Gast Supp 1: 22-27.

Kang Y, Yu-Jie Fu, Yuan-Gang Gu, Fang-Rong Chang, Yung-Husan Chen, Xiao-Lei Liu, Johannes Stelten, Hans-Martin Schiebel (2010) Cajanuslactone, a new coumarin with anti-bacterial activity from pigeon pea (Cajanus cajan (L.) Millsp.) leaves. Food Chem 121: 1150-1155.

Kunyanga C, Imungi J and Vellingiri V (2013) Nutritional evaluation of indigenous foods with potential food-based solution to alleviate hunger and malnutrition in Kenya. J App Biosci 67: 5277-5288.

Kuo SM, Merhige PM and Hagey LR (2013) The effect of dietary prebiotics and probiotics on body weight, large intestine indices, and fecal bile acid profile in wild type and IL10-/- mice. PLoS One, 8: e60270.

Lai YS, Hsu WH, Huang JJ and Wu SC (2012) Antioxidant and anti-inflammatory effects of pigeon pea (Cajanus cajan L.) extracts on hydrogen peroxide- and lipopolysaccharide-treated RAW264.7 macrophages. Food Function 3: 1294–301.

Lee BH, Lai YS, Wu SC (2015) Antioxidation, angiotensin converting enzyme inhibition activity, natto kinase, and anti-hypertension of Bacillus subtilis (natto)-fermented pigeon pea. Int J Clin Nutr 4: 127-134.

Longvah T, Ananthan R, Bhaskara Chary K and Venkaiah K (2017) Indian food composition tables. ICMR, New Delhi, India.

Luo M, Liu YM, Le L, Li ZY, Si JY, Liu XM, Chang Q, Pan RL (2014) Cajaninstilbene acid prevents corticosterone-induced apoptosis in PC12 cells by inhibiting the mitochondrial apoptotic pathway. Cell Phys Biochem 34: 1015-26.

John K, Di Baise, Daniel N, Frank and Ruchi Mathur (2012) Impact of the gut microbiota on the development of obesity: Current Concepts. American Journal of Gast Supp 1: 22-27.

Kang Y, Yu-Jie Fu, Yuan-Gang Gu, Fang-Rong Chang, Yung-Husan Chen, Xiao-Lei Liu, Johannes Stelten, Hans-Martin Schiebel (2010) Cajanuslactone, a new coumarin with anti-bacterial activity from pigeon pea (Cajanus cajan (L.) Millsp.) leaves. Food Chem 121: 1150-1155.

Kunyanga C, Imungi J and Vellingiri V (2013) Nutritional evaluation of indigenous foods with potential food-based solution to alleviate hunger and malnutrition in Kenya. J App Biosci 67: 5277-5288.

Kuo SM, Merhige PM and Hagey LR (2013) The effect of dietary prebiotics and probiotics on body weight, large intestine indices, and fecal bile acid profile in wild type and IL10-/- mice. PLoS One, 8: e60270.

Lai YS, Hsu WH, Huang JJ and Wu SC (2012) Antioxidant and anti-inflammatory effects of pigeon pea (Cajanus cajan L.) extracts on hydrogen peroxide- and lipopolysaccharide-treated RAW264.7 macrophages. Food Function 3: 1294–301.

Lee BH, Lai YS, Wu SC (2015) Antioxidation, angiotensin converting enzyme inhibition activity, natto kinase, and anti-hypertension of Bacillus subtilis (natto)-fermented pigeon pea. Int J Clin Nutr 4: 127-134.

Longvah T, Ananthan R, Bhaskara Chary K and Venkaiah K (2017) Indian food composition tables. ICMR, New Delhi, India.

Luo M, Liu YM, Le L, Li ZY, Si JY, Liu XM, Chang Q, Pan RL (2014) Cajaninstilbene acid prevents corticosterone-induced apoptosis in PC12 cells by inhibiting the mitochondrial apoptotic pathway. Cell Phys Biochem 34: 1015-26.

John K, Di Baise, Daniel N, Frank and Ruchi Mathur (2012) Impact of the gut microbiota on the development of obesity: Current Concepts. American Journal of Gast Supp 1: 22-27.

Kang Y, Yu-Jie Fu, Yuan-Gang Gu, Fang-Rong Chang, Yung-Husan Chen, Xiao-Lei Liu, Johannes Stelten, Hans-Martin Schiebel (2010) Cajanuslactone, a new coumarin with anti-bacterial activity from pigeon pea (Cajanus cajan (L.) Millsp.) leaves. Food Chem 121: 1150-1155.
