Chapter 3

Cowpea: A Strategic Legume Species for Food Security and Health

Alexandre Carneiro da Silva, Dyego da Costa Santos, Davair Lopes Teixeira Junior, Pedro Bento da Silva, Rosana Cavalcante dos Santos and Amauri Siviero

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.79006

Abstract

In this chapter, several characteristics of cowpea (*Vigna unguiculata*), including nutritional and nutraceutical properties, and economic and social aspects of production were analysed with the objective to demonstrate that cowpea is a culture suitable for inclusion in food security programs. Cowpea is rich in diverse nutrients, highlighting high levels of protein. Cowpea also is rich in nutraceuticals compounds such as dietary fibre, antioxidants and polyunsaturated fatty acids and polyphenols. Widely cultivated and consumed cowpea is the very important legume for the nutrition and health of millions of people in many countries. In addition to being nutritious and safe, cowpea has high relative productivity, production stability and high tolerance to environmental stresses such as drought. Cowpea also has economic viability, low environmental impact and contributes to the conservation of natural resources and the sustainability of production systems. Cowpea is a safe food, always available in most regions, low priced compared to other sources of protein. Based on the analyses performed, it is possible to infer that cowpea is a strategic culture for the promotion of food security and health of populations on all continents.

Keywords: diseases prevention, nutraceuticals, nutrition, phytochemicals, *Vigna unguiculata*

1. Introduction

At the historic reunion of 1996 in Rome, in World Food Summit of Food and Agriculture Organization of the United Nations (FAO), food security is met when "all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Due to its central role in human development, food security is recognized as a universal human right [1].

Promoting food security is a complex mission with political, economic, environmental, social and cultural dimensions. For food security to be achieved, the population should have unrestricted access to a healthy and nutritious diet, which depends on adequate economic resources and food available in the country, region and communities in which people are located. The national availability of food for human consumption is a function of the balance between food grown in the country, import and export of food, reduction of waste and destination of food [2]. At the cultural and sociopolitical level, countries must provide incentives for advancing locally based and culturally relevant ethnic foods. The critical knowledge and creativity gained from long-term accumulated traditional knowledge can inform contemporary food science and nutritional and health science to advance more sustainable strategies based on experiences of diverse ecologies and cultures around the world [3].

The health is directly related with the balanced nutrition. Hippocrates "the father of medicine", over two millennia ago, mentioned about 400 medicinal plants and uttered the maxim, "let food be your medicine and let medicine be your food" [4]. Nutraceutical is the hybrid of 'nutrition' and 'pharmaceutical'. Nutraceuticals, in broad, are food or part of food playing a significant role in modifying and maintaining normal physiological function that maintains healthy human beings [5]. Grain legumes contain numerous phytochemicals useful for their nutritional or nutraceutical properties [6].

During the last decade, legumes have emerged as an interesting and balanced source of nutrients, being currently widely cultivated and consumed in different parts of the world [7, 8]. Legumes are consumed worldwide as an alternative source of proteins, since they are rich in amino acids like lysine and tryptophan and they are much cheaper than animal proteins [5]. Legumes are an excellent source of many essential nutrients, including vitamins, minerals, fibres, antioxidants and other bioactive compounds [9–11], including enzyme inhibitors, lectins, phytates, oligosaccharides and phenolic compounds that play metabolic roles in humans consuming these foods frequently [12].

The health organizations around the world recommend consuming legumes as part of a healthy diet, particularly because they have an important role in the control and prevention of chronic non-communicable diseases (NCDs) such as diabetes, cardiovascular diseases and cancer [13–15]. The legumes also favour the control of body weight, since they give greater satiety, prevent the accumulation of fat at the abdominal level and regulate blood sugar levels [15–17].

Cowpea (*Vigna unguiculata* [L.] Walp) is grain legume originated in the African continent with large economic and social importance in the developing world. Cowpea is a food of major importance for millions of people, especially in less developed countries of the tropics, being the major source of protein and carbohydrate dietary of the large part of the world population. Cowpea is not only rich in nutrients, but also nutraceuticals such as dietary fibre, antioxidants and polyunsaturated fatty acids (PUFA) and polyphenols [18–21].

Widely consumed in many countries, with excellent nutritional and nutraceutical properties and several agronomic, environmental and economic advantages, contributing to food security and maintenance of environment [22, 23]; cowpea is a strategic culture for the promotion of food security and health of populations on all continents.

2. Production and food security

2.1. Aspects of production

Cowpea is one of the key food sources in the arid, semi-arid and tropical parts of Asia, Oceania, southern Europe, Africa, southern United States and Central and South America [24]. Cowpea is grown as a main legume crop in Africa (Egypt, Nigeria), South America (Colombia, Brazil), the USA, Mexico, Asia (China, Pakistan and Japan) and in South and Southeast Europe (Spain, Italy, Portugal, Greece and Cyprus) [25]. It is truly a multifunctional crop, providing food for man and livestock and serving as a valuable and dependable revenue-generating commodity for farmers and grain traders [24, 26–27].

According to the data from the Food and Agriculture Organization (FAO) (http://www.fao.org), approximately 5.8 million tons of dry cowpea cereal is produced annually with a minimum of 11 million hectares planted all over the world [27], an average productivity of 527 kg ha^{-1}. However, due to the low productivity in regions that grow cowpea for subsistence, with low technological level and use of traditional genotypes, this productivity is below the potential of the crop that is 6000 kg ha^{-1} [28].

Recent studies to evaluate the "adaptability and stability" and the productive performance of different genotypes (e.g. cultivar, lineage and hybrid) in different environmental conditions has allowed to obtain dry grain yields close and/or higher than 3000 kg ha^{-1} for various genotypes [29, 30]. In addition to the positioning of genotypes suitable to crop environments, simple adjustments in production systems such as determination of planting time, spacing and plant density, are capable of promoting large productivity increases. Therefore, increased productivity and economic viability of cowpea is possible in all growing regions, using appropriate genotypes and improvements in production systems, reducing dependence on external inputs.

Cowpea is an essential component of sustainable cropping systems in the sub-humid tropics and, generally, dry regions across the globe. Cowpea is particularly important as a rotation crop with cereals. Cowpea can enhance the fertility of the soil with respect to nitrogen and phosphate, thereby benefiting subsequent cereal crops [23, 24]. Cowpea has great realization capacity of "biological nitrogen fixation (BNF)". BNF converts the atmospheric dinitrogen (N2) into usable nitrogen (N) by plants. BNF occurs in specialized plant structure called nodules formed by the symbiosis between roots and diazotrophic bacteria, which confer to leguminous crops the ability to satisfy their own and other plants' N-source demand [31, 32].

Cowpea is able to fix N in an amount greater than 100 kg ha^{-1}, replacing nitrogen fertilization [33], contributes to the low production cost of this culture [34]. BNF has contributed to the increase in cowpea yield, which along with other technological strategies has led to the expansion of the culture to news agricultural frontiers, competing as off-season culture with traditional commodities, such as corn [35]. Besides the fixation of N, the inclusion of cowpea in the rotation crop systems favours the accumulation of organic matter and greater fixation of carbon. This accumulation of organic matter contributes to the improvement of soil fertility and physical characteristics such as water infiltration and retention capacity, soil conservation and sustainability of production systems.

2.2. A strategic culture for food security

Increasing demands for nutritious, safe and healthy food because of a growing population and the pledge to maintain biodiversity and other resources pose a major challenge to agriculture that is already threatened by changing climate [36]. The access to healthy diet depends on the availability of nutritious foods at prices compatible with the purchasing power of populations [2]. Therefore, for a crop to be included in food safety programs, in addition to being nutritious and safe, it must have high relative productivity, production stability and high tolerance to environmental stresses (e.g. drought, salt soil, high temperature). They must also have economic viability, low environmental impact and contribute to the conservation of natural resources and the sustainability of production systems.

Cowpea is one of the most important edible grain legumes in underdeveloped and developing countries contributing to food security and maintenance of environment for millions of small-scale farmers and of the local populations [22, 37–38]. In developed countries, cowpea is also considered as a healthy alternative to soya bean as consumers look to more traditional food sources that are low in fat and high in fibre and that have other health benefits [39].

The availability of food is directly related to the agricultural production policies of each nation, which defines the agricultural crops that will receive investments in research, development of production technologies, financing, as well as the destination of production. This is especially relevant in case of ethnically and culturally relevant legumes, such as cowpea, where food support and subsidies in many countries favour a restricted choice of cereal crops over balanced co-production of legumes [40].

The research investment combined with the wide genetic diversity allowed us to obtain high-yield productive cowpea genotypes, early maturity and with plant architecture favourable to the mechanized harvest. These genotypes have greater resistance to the adverse environmental conditions to the cultivar (e.g. dry and temperature variation) and the attack of pests and diseases. In the last decade, cowpeas have ceased to be a subsistence crop, cultivated largely by family farmers and have aroused the interest of large farmers. With this, the relative increase in cowpea production in the first decade of the twenty-first century surpassed all other pulses[1] [41]. Cowpea is truly a multifunctional crop strategic for food security.

[1] Pulses are defined by the FAO as "limited to crops harvested solely for dry grain, thereby. Pulses exclude vegetable crops such as green peas and green beans, crops which are used primarily such oil crops (e.g. soybeans) and leguminous forage crops, such as alfalfa [42].

3. Nutritional properties

Cowpea plays a critical role in the lives of millions of people in the developing world, providing them a major source of dietary protein that nutritionally complements low-protein cereal and tuber crop staples [39]. With recognised nutritional value, cowpea can be consumed such as mature beans (i.e. dried grain), green beans or green pods. The cowpea leaves also can be consumed as food. Grains, pods and leaves of the cowpea are processed and used as food ingredient by the food industry [43–46].

The cowpea seeds are eaten boiled, parched, fried, roasted, mixed with sauce or stewed and consumed directly. Its seeds provide important vitamins, phytonutrients including antioxidants besides carbohydrates, minerals and trace elements. Cowpea due to its nutrients and functional benefits has also gained industrial importance for being used as a potential ingredient in food formulations [47].

Regarding the need for consumption, nutrients in the human diet can be classified as macronutrients (primary contributors to energy intake, which include total carbohydrate, total fat, protein and alcohol), micronutrients (minerals, vitamins and dietary fibre), and to include other food components such as bioactive compounds [48].

The consumption of cowpea supplies most of the macro and micronutrients of the diet. Chemical composition and nutritional properties of cowpeas vary considerably according to cultivar. For effective utilization of newly developed cowpea cultivars for human nutrition, the removal or reduction of antinutrients and evaluation of their nutritional properties are necessary [49].

3.1. Macronutrients

3.1.1. Protein

The nutritional profile of cowpea grain is similar to that of other pulses with a relatively low fat content and total protein content that is two- to fourfold higher than cereal and tuber crops [39]. Under the Harvest Plus initiative funded by the Bill & Melinda Gates Foundation and others, a systematic breeding program to develop improved cowpea varieties with enhanced levels of protein and micronutrient contents was initiated in 2003. Approximately, 2000 genotypes (e.g. cultivars and breeding lines) have been evaluated revealing significant genetic variability in seed protein contents, with values ranging from 21 to 30.7% [39]. The nutritional ranking of 30 Brazilian genotypes of cowpea revel protein contents ranging from 17.4 to 28.3%. [50]. For improved cowpea breeding lines, the protein content can be bigger than 30% [51, 52].

Similar to other pulses, the storage proteins in cowpea seeds are rich in the amino acids lysine and tryptophan when compared to cereal grains, but low in methionine and cysteine when compared to animal proteins [39]. Cowpea possess some undesirable properties that are common to other legume seeds, such as methionine and cysteine deficiency as well as considerable contents of antinutritional factors like protease inhibitors, lectins, phytic acid, tannins, among others [49, 53].

A protein has a good amino profile when it presents all the essential amino acids (i.e. those that cannot be synthesised by the body and therefore must be obtained by the diet) in significant quantity [54]. Genetic and agronomic factors may influence the amino acid profile of cowpea [55]. Analyses carried out by Frota et al. [56] and Vasconcelos et al. [57] have shown that cowpea presented cysteine and methionine as limiting amino acids, whereas the other essential amino acids met the recommendations of the amino acid standard of the FAO/WHO [58] for children (2–5 years). However, other authors have found values of all the essential amino acids below the recommendation in some cowpea cultivars [59, 60].

Given its nutritional value as well as the reduced environmental impact of the production systems, intense research efforts must be redirected to the evaluation of nutrients and antinutrients of cowpea, its digestibility and development of processing alternatives that may allow the production of foods with lower impact on human health as well as its potential contribution to human nutrition [7]. Conventional processing methods, such as soaking, boiling, germination and fermentation, are widely used to decrease the content of these undesirable components, which results in enhanced acceptability and nutritional quality in addition to optimal utilisation of this legume as human food [61].

Cowpea protein isolate is an alternative for incorporation into food products [56]. Protein isolation is an alternative for the minimisation of antinutritional factors, improved digestibility and bioavailability of leguminous amino acids [62]. A mixed food of legumes and cereals, particularly in developing countries, can compensate deficiencies or a low level of lysine and sulphur amino acids, in cereals and grain legumes, respectively [63]. The utilization of a nutritional quality index will allow pinpointing the genotypes that gather the largest number of desirable nutritional attributes and then assist in the planning of new crosses in the breeding program [50].

3.1.2. Carbohydrate

Cowpea is one of the main sources of calories for a large segment of world population [18, 57]. Cowpea seeds contain approximately 53–66% carbohydrate, most of which is found in the form of starch, has high amylose content and C-type starch crystallinity [64–66].

Legumes, such as cowpea, contain a considerable amount of resistant starch (i.e. starch that resists to digestion by amylase in the small intestine and progresses to the large intestine for fermentation by the gut bacteria) and also have a higher ratio of slow-digestible to rapid-digestible starch, compared to other carbohydrate foods. Resistant starch is associated with reduced glycemic response, which can be beneficial to insulin-resistant individuals and those with diabetes [67–69]. Carbohydrates that are digested slowly also result in a low glycemic index (GI) [70]. The consumption of low GI foods could prevent the emergence of several diseases, such as obesity, diabetes, cardiovascular diseases and even certain cancers [71]. Other important constituents in cowpea seeds are the α-galactosides, with a recognized prebiotic function [72].

3.1.3. Lipids

Recently, cowpea has been stressed on a low fat content, comparatively to other legumes (chickpea, split pea, lentil, green gram and lupine), which makes it, according to nutritional guidelines, a legume with potential application in weight restriction diets [7]. The content and profile of lipids in cowpea seeds, such as other nutrients, vary among genotypes and are also influenced by environmental conditions during cultivation. According to Brazilian Agricultural Research Corporation (EMBRAPA), the content of lipids in cowpea seeds, on average, is 2% [73]. The nutritional ranking of 30 Brazilian genotypes of cowpea revel lipids contents range from 1.0 to 1.6% [50]. Frota et al. [74], found lipid content of 2.2% in seed cowpea BRS-Milênio, a cultivar obtained by genetic improvement, and its fatty acids profile was 29.4% saturated and 70.7% unsaturated. Iqbal et al. [13], on the other hand, obtained approximately double the lipid content (4.8 g 100 g^{-1}) in relation to the cultivar BRS-Milênio analysed in the study performed by Frota et al. [74].

The triglycerides are the most abundant lipids in the cowpea seeds, corresponding to 41.2% of the total fat. The cowpea seeds lipid profile includes still 25.1% of phospholipids, 10.6% of monoglycerides, 7.9% of free fatty acids, 7.8% of diglycerides, 5.5% of sterols and 2.6% of hydrocarbons + sterol esters [75, 76]. Of the total fatty acids, most of it (40.1–78.3%) consists of polyunsaturated fatty acids. Ranging from 20.5 to 67.1%, the palmitic acid is the most abundant fatty acid. The content of linoleic acid can be ranging from 20.8 to 40.3% and of the linolenic acid ranges from 9.6 to 30.9%. In smaller proportion (2.9–14.0%), the stearic acids complete the profile of fatty acids of the cowpea seeds [7].

3.2. Micronutrients

Micronutrients are organic or inorganic compounds present in small amounts and are not used for energy, but are nonetheless needed for good health. Nonessential micronutrients encompass a vast group of unique organic phytochemicals that are not strictly required in the diet, but when present at sufficient levels are linked to the promotion of good health. Essential micronutrients in the human diet include 17 minerals and 13 vitamins required at minimum levels to alleviate nutritional disorders (See [77]).

3.2.1. Vitamin

Cowpea is rich in vitamin A and C and also has appreciable amount of thiamin, riboflavin, niacin, vitamin B6 and pantothenic acid as well as small amount of foliate [78]. Vitamins are indispensable to the maintenance of various functions of physiological importance such as muscle contractility, nerve function, blood coagulation, digestive processes and acid–base balance [79].

The major vitamins present in cowpea are those belonging to the B complex, being reported in the following decreasing order: niacin (7.0–40.0 × 10^{-3} g kg^{-1}) > panthothenic acid (17.0–22.0 × 10^{-3} g kg^{-1}) > thiamine (2.0–17.0 × 10^{-3} g kg^{-1}) > pyridoxine (2.0–4.0 × 10^{-3} g kg^{-1}) > folic acid (1.0–4.0 × 10^{-3} g kg^{-1}) > riboflavin (1.0–3.0 × 10^{-3} g kg^{-1}) > biotin(0.2–0.3 × 10^{-3} g kg^{-1}) > cobalamin (traces). Cowpea appears to be a particularly good source of vitamin C, with levels in seeds ranging from 52.0 to 554.0 × 10^{-3} g kg^{-1}. Carotenoids, precursors of vitamin A, are also present in cowpea contributing to the antioxidant compounds provided by this legume. Lastly, from the various vitamin E vitamers present in cowpea, δ-tocopherol has been observed with the highest concentration (15.1–109.7 × 10^{-3} g kg^{-1}), followed by γ-tocopherol (4.3–92.3 × 10–3 g kg^{-1}), and γ-tocotrienol (0.7–3.4 × 10^{-3} g kg^{-1}). The vitamin E composition of cowpea seems to differ significantly from that of most legumes, where γ-tocopherol dominates (reviewed by [7]).

3.2.2. Minerals

An appropriate intake of micro minerals is necessary for the human organism to meet its metabolic needs, and hence avoid a wide range of associated health problems [80, 81]. Cowpea is rich in potassium with good amount of calcium, magnesium and phosphorus. It also has small amount of iron, sodium, zinc, copper, manganese and selenium [78].

The mineral composition of 30 newly developed Brazilian cowpea genotypes obtained by conventional plant breeding reveals the following contents of minerals in the seeds: iron 61–81 ppm; zinc 27–44 ppm; sodium 84–177 ppm; potassium 9570–12,510 ppm; calcium 290–440 ppm; magnesium 1310–1160 ppm; manganese 17–29 ppm; copper 20–22 ppm [50].

The cowpea seed analysis of 87 lines originated from a set of crosses involving 3 accessions of the IITA ('IT97K-1042-3', 'IT99K-216-48-1' and 'IT97K-499') and accessions adapted for cultivation in the Brazilian semi-arid tropical areas ('BRS Tapaihum', 'BRS Pujante' and 'Canapu'), reveals high variation in minerals values: calcium 420–6260 ppm; iron 42.0–137.0 ppm; zinc 38.0–55.5 ppm; potassium 21,000–27,000 ppm; sodium 29.2–88.0 ppm [80]. In the analysis of approximately 2000 cowpea genotypes under the Harvest Plus initiative [39], the typical calcium, iron, zinc and potassium values showed large variations among genotypes (e.g. calcium ranging from 545 to 1300 ppm and zinc ranging from 23 to 48 ppm). These analyses reveal that cowpea have high levels of these micronutrients in comparison with other cultures, and that the variation in the levels of these micronutrients favours the genetic improvement of the species and the obtaining of more nutritious genotypes [39, 80].

4. Nutraceuticals compounds

Nutraceuticals, in broad, are food or part of food playing a significant role in modifying and maintaining normal physiological function that maintains healthy human beings [5]. The food sources used as nutraceuticals are all natural and can be categorized as dietary fibre, probiotics, prebiotics, polyunsaturated fatty acids, antioxidant vitamins, polyphenols and other different types of herbal/natural foods [5, 82, 83].

4.1. Dietary fibre

Dietary fibre has been shown to have important health implications in the prevention of risks of chronic diseases such as cancer, CVD and diabetes mellitus [84]. Dietary fibre can be soluble or insoluble depending upon solubility in water. Cowpea has high level of dietary fibre, mainly of insoluble fibre. Water-soluble fibre can form viscous solutions. The insoluble fibre (i.e. lignin, cellulose and hemicellulose) has high water-holding capacity and acts on the regulation of the defecation process [12, 13], while that the soluble fibre can contribute for reducing the postprandial blood glucose and insulin levels, and serum cholesterol [85].

In cowpea flours, (i.e. dehulled, ground and defatted cotyledons) the total dietary fibre (calculated as % of dry matter) is 14.1 ± 0.3, being 1.0 ± 0.0% of soluble fibre and 13 ± 0.2 of insoluble fibre

[86]. The dietary fibre composition of 30 newly developed Brazilian cowpea genotypes showed great genetic variability among the genotypes, with values ranging from 19.5 to 35.6 g 100 g^{-1} [50].

4.2. Probiotics

Probiotics can be defined as live microbial feed supplements that beneficially affect the host animal by improving its intestinal microbial balance [87]. Food cultures that have such beneficial effects on human health have been termed "probiotic" [88].

Probiotics are associated with fermented foods, latter having a long tradition of acceptability in communities where they are produced, safe use and the established as well as postulated claims of health benefits [89, 90]. The probiotic potential of fermented foods, such as cowpea, sorghum and peanut plant seed extracts have been reported [91].

4.3. Prebiotics

Prebiotics are non-digestible food ingredients that selectively stimulating the growth and/or activity of one or a limited number of beneficial bacteria in the colon [92, 93]. The prebiotics resist hydrolysis by digestive enzymes and/or are not absorbed in the upper part of the gastrointestinal tract and pass into the large bowel and promote the growth of *Bifidobacterium* and *Lactobacillus*, contributing for the right balance of intestinal bacterial flora and the immune system. The growth of *Bifidobacterium* and *Lactobacillus* to dominate pathogenic organisms and thus invigorate human health is facilitated by certain oligosaccharides [94, 95]. Cowpea seeds are rich in α-galactosides (raffinose, stachyose and verbascose) [7, 96], also known as the raffinose family oligosaccharides (RFOs) [99].

The α-galactosides are beneficial compounds when ingested in amounts up to 3 g day^{-1}. However, when consumed in high doses the α-galactosides can cause flatulence and interference with the absorption of other nutrients during the digestive process [97]. As RFO act as substrate for intestinal bacteria, they are also considered as prebiotics [98]. The Galactosyl-cyclitols, present in legume seeds, are considered as important phytochemicals related to disease prevention [99].

4.4. Polyunsaturated fatty acids

Polyunsaturated fatty acids (PUFAs) are also called "essential fatty acids" as these are crucial to the body's function and are introduced externally through the diet [100]. PUFAs have two subdivisions: omega-3- (n-3) fatty acids and omega-6-(n-6) fatty acids. In cowpea, the bulk of fatty acids consist of polyunsaturated fatty acids that range from 40.1 to 78.3% of total (reviewed by [7]). This high level of unsaturated fatty acids is a nutritionally desirable feature [101].

Studies suggest that PUFAs have therapeutic effects in cardiovascular and hypolipidemic diseases. Emerging research evidence shows the benefits of omega-3-oils in other areas of health including premature infant health, asthma, bipolar and depressive disorders, dysmenorrhea and diabetes (reviewed by [5]).

4.5. Antioxidant vitamin

Cowpea appears to be a particularly good source of vitamin C, with levels in seeds and pods ranging from 52.0 to 554.0 × 10^{-3} g kg^{-1} [7]. Carotenoids, precursors of vitamin A, are also present in cowpea contributing to the antioxidant compounds provided by this legume. Among the carotenoids present in cowpea seeds, lutein makes up over 70.0%.Other carotenoids present in cowpea are β-carotene, γ-carotene and cryptoxanthin [7, 102].

From the various vitamin E vitamers present in cowpea, δ-tocopherol has been observed with the highest concentration, followed by γ-tocopherol -tocotrienol (0.7–3.4 × 10^{-3} g $kg^{-1)}$ [7]. The vitamin E composition of cowpea seems to differ significantly from that of most legumes, where γ-tocopherol dominates [103, 104].

4.6. Phenolic compounds

Cowpea is a good source of dietary phenolics mainly phenolic acids, flavonoids and anthocyanins and proanthocyanidins. These compounds are reportedly responsible for the antioxidant and other health promoting properties of cowpea [105].

Phenolic compounds (tannins, flavonoids and phenolic acids) are secondary metabolites in plants and are present in some plant foods [106, 107]. Phenolic compounds are responsible for various beneficial effects in a multitude of diseases [108]. Phenolic compounds have antioxidant properties and ability to modulate the activity of various enzymes. These phenolics are also potent inhibitors of a-amylase and a-glucosidase, the two important enzymes involved in the regulation of glucose homeostasis [109].

5. Conclusion

In the current scenario of population growth, the demand for nutritious and functional, safe, and healthy food poses a major challenge for producers, which in times of climate change are enjoined to conserve natural resources, and for the governments of nations in need invest in the production of crops that can be included in food security programs and contribute to the health of populations.

With excellent nutritional and nutraceutical properties and several agronomic, environmental and economic advantages, cowpea is able of contribute to food security, maintenance of environment and promotion health for populations. This is possible due to the great genetic variability of the cowpea and the numerous researches to develop new genotypes more productive, biofortified, adapted to different environments and production systems. Cowpea is a much studied culture, which has its composition known, with great value for the food industry.

The use of cowpea as functional food has encouraged the industry and farmers to produce this legume. Considering the great demand worldwide for consumption, the excellent nutritional and nutraceutical properties, the availability of production technology and the wide possibility of choice of genotypes for production, cowpea is undoubtedly a strategic legume specie for food security and health.

Acknowledgements

The author thank the Coordination for the Improvement of Higher Education Personnel (CAPES-Brazil).

Author details

Alexandre Carneiro da Silva[1]*, Dyego da Costa Santos[1], Davair Lopes Teixeira Junior[1], Pedro Bento da Silva[2], Rosana Cavalcante dos Santos[3] and Amauri Siviero[4]

Address all correspondence to: alexandre.silva@ifac.edu.br

1 Federal Institute of Education, Science and Technology of Acre (IFAC), Xapuri, Acre State, Brazil

2 Sacred Heart University (USC), Bauru, São Paulo State, Brazil

3 Federal Institute of Education, Science and Technology of Acre (IFAC), Rio Branco, Acre State, Brazil

4 Brazilian Agricultural Research Corporation, Rio Branco, Acre State, Brazil

References

[1] FAO. World Food Summit [Internet]. Rome (Italy): FAO; 1996. [cited 2018 Abr 5]. Available from: http://www.fao.org/wfs/index_en.htm

[2] Pérez-Escamilla R. Food Security and the 2015-2030 Sustainable Development Goals: From Human to Planetary Health: Perspectives and Opinions. Current Developments in Nutrition. 2017;**1**(7):e000513

[3] Shetty K, Sarkar D. Advancing Ethnic Foods in Diverse Global Ecologies through Systems-Based Solutions is Essential to Global Food Security and Climate Resilience-Integrated Human Health Benefits; 2018

[4] Shultes RE. The kingdom of plants. In: Thomson WAR, editor. Medicines from the Earth. New York, NY: McGraw-Hill Book Co; 1978. p. 208

[5] Das L, Bhaumik E, Raychaudhuri U, Chakraborty R. Role of nutraceuticals in human health. Journal of Food Science and Technology. 2012;**49**(2):173-183

[6] Boschin G, Arnoldi A. Legumes are valuable sources of tocopherols. Food Chemistry. 2011;**127**(3):1199-1203

[7] Gonçalves A, Goufo P, Barros A, Domínguez-Perles R, Trindade H, Rosa EA, et al. Cowpea (*Vigna unguiculata* L. Walp), a renewed multipurpose crop for a more sustainable

agri-food system: nutritional advantages and constraints. Journal of the Science of Food and Agriculture. 2016;**96**(9):2941-2951

[8] Rajan K, Ankur T. Nutraceutical and pharmacological properties of Vigna species. Indian Journal of Agricultural Biochemistry. 2017;**30**(1):10-20

[9] Shimelis AE, Rakshit SK. Anti-nutritional factors and in vitro protein digestibility of improved haricot bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. Inter J. Food Science & Nutrition. 2005;**56**:377-387

[10] Sharma G, Srivastava AK, Prakash D. Phytochemicals of nutraceutical importance: Their role in health and diseases. Pharmacology. 2011;**2**:408-427

[11] Prakash D, Gupta C. Role of phytoestrogens as nutraceuticals in human health. Pharmacology. 2011;**1**:510-523

[12] Campos-Vega R, Loarca-Pina G, Dave Oomah B. Minor components of pulses and their potential impact on human health. Foodservice Research International. 2010;**43**:461-482

[13] Iqbal A, Khalil IA, Ateeq N, Sayyar Khan M. Nutritional quality of important food legumes. Food Chemistry. 2006;**97**(2):331-335

[14] United Nations (2014): Resolution adopted by the General Assembly on 20 December 2013, 68/231. International Year of Pulses 2016. A / RES / 68/231

[15] Clifton PM. Legumes and cardiovascular disease. In: Bioactive Foods in Promoting Health. San Diego: Elsevier Inc; 2010. pp. 449-455

[16] Tharanathan R, Mahadevamma S. Grain legumes–a boon to human nutrition. Trends in Food Science and Technology. 2003;**14**(12):507-518

[17] Williams PG, Grafenauer SJ, O'Shea JE. Cereal grains, legumes, and weight management: A comprehensive review of the scientific evidence. Nutrition Reviews. 2008;**66**:171-182

[18] Phillips RD, McWatters KH, Chinnan MS, Hung YC, Beuchat LR, Sefa-Dedeh S, Sakyi-Dawson E, Ngoddy P, Nnanyelugo D, Enwere J, Komey NS, Liu K, Mensa-Wilmot Y, Nnanna IA, Okeke C, Prinyawiwatkul W, Saalia FK. Utilization of cowpeas for human food. Field Crops Research. 2003;**82**:193-213

[19] Trinidad TP, Mallillin AC, Loyola AS, Sagum RS, Encabo RR. The potential health benefits of legumes as a good source of dietary fibre. British Journal of Nutrition. 2010;**103**(4):569-574

[20] Shetty AA, Magadum S, Managanvi K. Vegetables as sources of antioxidants. Journal of Food and Nutritional Disorders. 2013;**2**(1):2

[21] Baptista A, Pinho O, Pinto E, Casal S, Mota C, Ferreira IM. Characterization of protein and fat composition of seeds from common beans (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata* L. Walp) and bambara groundnuts (*Vigna subterranea* L. Verdc) from Mozambique. Journal of Food Measurement and Characterization. 2017;**11**(2):442-450

[22] Tarawali SA, Singh BB, Gupta SC. Cowpea as a key factor for a new approach to integrate crop-livestock systems research in dry savannas of West Africa. In: Challenges and opportunities for enhancing sustainable cowpea production. Proceedings of the world cowpea conference III held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria; 2002

[23] Hall A. Phenotyping cowpeas for adaptation to drought. Frontiers in Physiology. 2426;**3, 2012**:155

[24] Singh BB, Ehlers JD, Sharma B, Freire Filho FR. Recent progress in cowpea breeding. In: Fatokun CA, Tarawali SA, Singh BB, Kormawa PM, Tamò M, editors. Challenges and Opportunities for Enhancing Sustainable Cowpea Production. Ibadan: International Institute of Tropical Agriculture; 2002. pp. 4-8

[25] Antova GA, Stoilova TD, Ivanova MM. Proximate and lipid composition of cowpea (*Vigna unguiculata* L.) cultivated in Bulgaria. Journal of Food Composition and Analysis. 2014;**33**(2):146-152

[26] Langyintuo AS, Lowenberg-DeBoer J, Faye M, Lamber D, Ibro G, et al. Cowpea supply and demand in West Africa. Field Crops Research. 2003;**82**:215-231

[27] Xiong H, Shi A, Mou B, Qin J, Motes D, Lu W, Wu D. Genetic diversity and population structure of cowpea (*Vigna unguiculata* L. Walp). PLoS One. 2016;**11**(8):e0160941

[28] Freire Filho FR, Ribeiro VQ, Barreto PD, Santos AA. Melhoramento genético. In: Freire Filho FR, Lima JAA, Ribeiro VQ, editors. Feijão-caupi: avanços tecnológicos. Brasília: Embrapa Informação Tecnológica; 2005. pp. 27-92

[29] GUERRA JVS, CARVALHO AJD, Medeiros JC, SOUZA AAD, Brito OG. Agronomic performance of erect and semi-erect cowpea genotypes in the north of Minas Gerais, Brazil. Revista Caatinga. 2017;**30**(3):679-686

[30] Draghici R, Draghici I, Diaconu A, Dima M. Variability of genetic resources of cowpea (*Vigna unguiculata*) studied in the sandy soil conditions from Romania. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series. 2017;**46**(1):147-153

[31] Giller KE. Nitrogen Fixation in Tropical Cropping Systems. Wallingford: CAB International; 2001

[32] Udvardi M, Poole PS. Transport and metabolism in legume-rhizobia symbioses. Annual Review of Plant Biology. 2013;**64**:781-805. DOI: 10.1146/annurev-arplant-050312-120235

[33] Araújo JPP, Watt EE. O caupí no Brasil. IITA/EMBRAPA: Brasília; 1988. p. 722

[34] Rangel OJP, Silva CA. Estoques de carbono e nitrogênio e frações orgânicas de Latossolo submetido a diferentes sistemas de uso e manejo. Revista Brasileira de Ciência do Solo, Viçosa. 2007;**31**(6):1609-1623

[35] Freire Filho FR. Feijão-caupi no Brasil: produção, melhoramento genético, avanços e desafios. 1st ed. Teresina, PI: Embrapa; 2011. p. 84

[36] Dwivedi SL, van Bueren ETL, Ceccarelli S, Grando S, Upadhyaya HD, Ortiz R. Diversifying food systems in the pursuit of sustainable food production and healthy diets. Trends in Plant Science. 2017;**22**(10):842-856

[37] Maia FMM, Oliveira JTA, Matos MRT, Moreira RA, Vasconcelos IM. Proximate composition, amino acid content and haemagglutinating and trypsin-inhibiting activities of some Brazilian *Vigna unguiculata* (L) Walp cultivars. Journal of the Science of Food and Agriculture. 2000;**80**(4):453-458

[38] Davis DW, Delke EA, Oplinger ES, Hanson CV, Putnam DH. Alternative Field Crop Manual, Department of Horticultural Science, Agronomy and Plant Genetics; Center for Alternative Plant and Animals Products. U.S.A: Minnesota Extension Service, University of Minnesota; 2013

[39] Timko MP, Singh BB. Cowpea, a multifunctional legume. In: Genomics of Tropical Crop Plants. NY: Springer, New York; 2008. pp. 227-258

[40] Shetty K. Systems Solutions to Global Food Security Challenges to Advance Human Health and Global Environment Based on Diverse Food Ecology Sustainable Investment Produce, 65

[41] Singh BB. Future Prospects of Cowpea. Cowpea: The Food Legume of the 21st Century, n. cowpeathefoodle; 2014. pp. 145-157

[42] Tiwari B, Singh N. Pulse Chemistry and Technology. Royal Society of Chemistry; 2012

[43] Frota KMG, Mendonca S, Saldiva PHN, Cruz RJ, Areas JAG. Cholesterol-lowering properties ofwhole cowpea seed and its protein isolate in hamsters. Journal of Food Science. 2008;**73**:H235-H240

[44] Kapravelou G, Martinez R, Andrade AM, Chaves CL, Lopez-Jurado M, Aranda P, et al. Improvement of the antioxidant and hypolipidaemic effects of cowpea flours (*Vigna unguiculata*) by fermentation: results of in vitro and in vivo experiments. Journal of the Science of Food and Agriculture. 2015;**95**:1207-1216

[45] Xiong SL, Yao XL, Li AL. Antioxidant properties of peptide from cowpea seed. International Journal of Food Properties. 2013;**16**:1245-1256

[46] Xu BJ, Chang SKC. Comparative study on antiproliferation properties and cellular antioxidant activities of commonly consumed food legumes against nine human cancer cell lines. Food Chemistry. 2012;**134**:1287-1296

[47] Bello SK, Yusuf AA, Cargele M. Performance of cowpea as influenced by native strain of rhizobia, lime and phosphorus in Samaru, Nigeria. Symbiosis. 2017;**35**:1-10

[48] Bialostosky K, Wright JD, Kennedy-Stephenson J, McDowell M, Johnson CL. Dietary intake of macronutrients, micronutrients, and other dietary constituents: United States, 1988-94: data from the National Health Examination Survey, the National Health and Nutrition Examination Surveys, and the Hispanic Health and Nutrition Examination Survey; 2002

[49] Giami SY. Compositional and nutritional properties of selected newly developed lines of Cowpea (*Vigna unguiculata* L. Walp). Journal of Food Composition and Analysis. 2005;**18**:665-673

[50] Carvalho AFU, de Sousa NM, Farias DF, da Rocha-Bezerra LCB, da Silva RMP, Viana MP, de Morais SM. Nutritional ranking of 30 Brazilian genotypes of cowpeas including determination of antioxidant capacity and vitamins. Journal of Food Composition and Analysis. 2012;**26**(1-2):81-88

[51] Nielsen SS, Brandt WE, Singh BB. Genetic variability for nutritional composition and cooking time of improved cowpea lines. Crop Science. 1993;**33**:469-472

[52] Santos CAF, Boiteux LS. Breeding biofortified cowpea lines for semi-arid tropical areas by combining higher seed protein and mineral levels. Genetics and Molecular Research. 2013;**12**(4):6782-6789

[53] Duranti M. Grain legume proteins and nutraceutical properties. Fitoterapia. 2006;**77**:67-82

[54] Boye J, Wijesinha-Bettoni R, Burlingame B. Protein quality evaluation twenty years after the introduction of the protein digestibility corrected amino acid score method. The British Journal of Nutrition. 2012;**108**(S2):S183-S211

[55] Pandurangan S et al. Differential response to sulfur nutrition of two common bean genotypes differing in storage protein composition. Frontiers in Plant Science. 2015;**6**:92

[56] Frota KDMG, Lopes LAR, Silva ICV, Arêas JAG. Nutritional quality of the protein of *Vigna unguiculata* L. Walp and its protein isolate. Revista Ciência Agronômica. 2017; **48**(5SPE):792-798

[57] Vasconcelos IM et al. Protein fractions, amino acid composition and antinutritional constituents of high-yielding cowpea cultivars. Journal of Food Composition and Analysis. 2010;**23**(1):54-60

[58] Food and Agriculture Organization; World Health Organization. Report of a joint FAO/WHO expert consultation. Protein Quality Evaluation. Pomegranate; 1991. p. 66 (FAO Food and Nutrition Paper, 51)

[59] Anjos F et al. Chemical composition, amino acid digestibility, and true metabolizable energy of cowpeas as affected by roasting and extrusion processing treatments using the cecectomized rooster assay. The Journal of Applied Poultry Research. 2016;**25**(1):85-94

[60] Elhardallou S et al. Amino acid composition of cowpea (Vigna ungiculata L. Walp) flour and its protein isolates. Food and Nutrition Sciences. 2015;**6**(9):790-797

[61] Kadam SS, Salunkhe DK. Nutritional composition, processing, and utilization of horse gram and moth bean. Critical Reviews in Food Science and Nutrition. 1985;**22**:1-26

[62] Sarwar G, Xiao C, Cockell KA. Impact ofantinutritional factors in food proteins on the digestibility ofprotein and the bioavailability of amino acids and on protein quality. The British Journal of Nutrition. 2012;**108**(S2):S315-S332

[63] Elhardallou SB, Khalid II, Gobouri AA, Abdel-Hafez SH. Amino acid composition of cowpea (Vigna ungiculata L. Walp) flour and its protein isolates. Food and Nutrition Sciences. 2015;**6**(9):790

[64] Hoover R, Hughes T, Chung HJ, Liu Q. Composition, molecular structure, properties and modification of pulse starches: A review. Food Research International. 2010;**43**:399-413

[65] Ashogbon AO, Akintayo ET. Isolation and characterization of starches from two cowpea (*Vigna unguiculata*) cultivars. International Food Research Journal. 2013;**20**:3093-3100

[66] Ratnaningsih N, Suparmo EH, Marsono Y. Composition, microstructure and physico-chemical properties of starches from Indonesian cowpea (*Vigna unguiculata*) varieties. International Food Research Journal. 2016;**23**:2041-2049

[67] Yamada Y, Hosoya S, Nishimura S, Tanaka T, Kajimoto Y, Nishimura A, Kajimoto O. Effect of bread containing resistant starch on postprandial blood glucose levels in humans. Bioscience, Biotechnology, and Biochemistry. 2005;**69**:559-566

[68] Park OJ, Kang NE, Chang MJ, Kim WK. Resistant starch supplementation influences blood lipid concentrations and glucose control in overweight subjects. Journal of Nutritional Science and Vitaminology. 2004;**50**:93-99

[69] Thorne MJ, Thompson LU, Jenkins DJ. Factors affecting starch digestibility and the glycemic response with special reference to legumes. The American Journal of Clinical Nutrition. 1983;**38**:481-488

[70] Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values. The American Journal of Clinical Nutrition. 2002;**76**:55-56

[71] Du SK, Jiang H, Ai Y, Jane JL. Physicochemical properties and digestibility of common bean (*Phaseolus vulgaris* L.) starches. Carbohydrate Polymers. 2014;**108**:200-205

[72] Martínez-Villaluenga C, Frías J, Vidal-Valverde C. Alpha-Galactosides: antinutritional factor or functional ingredients? Critical Reviews in Food Science and Nutrition. 2008;**48**:301-316

[73] Embrapa Meio-Norte. Cultivo de feijão caupi. Jul/2003. Disponível em:. Acesso em: 8 mar. 2007

[74] Frota KDMG, Soares RAM, Arêas JAG. Composição química do feijão caupi (*Vigna unguiculata* L. Walp), cultivar BRS-Milênio. Ciência e Tecnologia de Alimentos. 2008; **28**(2):470-476

[75] Antova GA, Stoilova TD, Ivanova MM. Proximate and lipid composition of cowpea (*Vigna unguiculata* L.) cultivated in Bulgaria. Journal of Food Composition and Analysis. 2014;**33**:146-152

[76] Zia-Ul-Haq M, Ahmad S, Chiavaro E, Mehjabeen AS, Sagheer A. Studies of oil from cowpea (*Vigna unguiculata* (L.) Walp) cultivars commonly grown in Pakistan. Pakistan Journal of Botany. 2010;**42**:1333-1341

[77] DellaPenna D. Nutritional genomics: manipulating plant micronutrients to improve human health. Science. 1999;**285**(5426):375-379

[78] Asare AT, Agbemafle R, Adukpo GE, Diabor E, Adamtey KA. Assessment of functional properties and nutritional composition of some cowpea (*Vigna unguiculata* L.) genotypes in Ghana. Journal of Agricultural and Biological Science. 2013;**8**(6):465-469

[79] HARDISSON A et al. Mineral composition of the banana (*Musa acuminata*) from the island of Tenerife. Food Chemistry. 2001;**73**:153-161

[80] Santos CAF, Boiteux LS. Breeding biofortified cowpea lines for semi-arid tropical areas by combining higher seed protein and mineral levels. Genetics and Molecular Research. 2013;**12**(4):6782-6789

[81] Welch RM, Graham RD. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany. 2004;**55**:353-364

[82] Kokate CK, Purohit AP, Gokhale SB. Nutraceutical and Cosmaceutical. Pharmacognosy. 21st ed. Pune, India: Nirali Prakashan; 2002. pp. 542-549

[83] Kalia AN. Textbook of Industrial Pharmacognosy. New Delhi: CBS Publisher and Distributor; 2005. pp. 204-208

[84] Roberfroid M. Health benefits of non-digestible oligosaccharides. In: Kritchevsky D, Bonfield C, editors. Dietary Fiber in Health and Disease (Advances in Experimental Biology). New York: Plenum Press; 1997. p. 427

[85] Anderson JW, Chen WJL. Cholesterol-lowering properties of oat products. In: Webster FH, editor. Oats Chemistry and Technology. St Paul, MN: American Association of Cereal Chemists; 1986. pp. 309-333

[86] Sreerama YN, Sashikala VB, Pratape VM, Singh V. Nutrients and antinutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. Food Chemistry. 2012;**131**(2):462-468

[87] Rolfe RD. The role of probiotic cultures in the control of gastrointestinal health. Journal of Nutrition. 2000;**130**:396S-402S

[88] Fuller R. Probiotics in man and animals. Journal of Applied Bacteriology. 1989;**66**:365-378

[89] Lei V, Jakobsen M. Microbiological characterization and probiotic potential of koko and koko sour water, an African spontaneously fermented millet porridge and drink. Journal of Applied Microbiology. 2004;**96**:384-397

[90] Vasiljevic T, Shah NP. Probiotics. From Metchnikoff to bioactives. International Dairy Journal. 2008;**18**:714-728

[91] Schaffner DW, Beuchat LR. Fermentation of aqueous plant seed extracts by lactic acid bacteria. Applied and Environmental Microbiology. 1986;**51**:1072-1076

[92] Gibson GR, Roberfroid MB. Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. The Journal of Nutrition. 1995;**125**:1401-1412

[93] Swennen K, Courtin CM, Delcour JA. Non-digestible oligosaccharides with prebiotic properties. Critical Reviews in Food Science and Nutrition. 2006;**46**:459-471

[94] Salminen S, Bouly C, Boutron-Ruault MC, Cummings JH, Franck A, Gibson GR, Isolauri E, Moreaou MC. Functional food science and gastrointestinal physiology and function. The British Journal of Nutrition. 1998;**80**:S147-S171

[95] Roberfroid M. Functional food concept and its application to prebiotics. Digestive and Liver Disease. 2002;**34**:S105-S110

[96] Sreerama YN, Sashikala VB, Pratape VM, Singh V. Nutrients and antinutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. Food Chemistry. 2012;**131**(2):462-468

[97] Martínez-Villaluenga C, Frías J, Vidal-Valverde C. Alpha-galactosides: antinutritional factors or functional ingredients? Critical Reviews in Food Science and Nutrition. 2008;**48**(4):301-316

[98] Swennen K, Courtin CM, Delcour JA. Non-digestibleoligosaccharides with prebiotic properties. Critical Reviews in Food Science and Nutrition. 2006;**46**:459-471

[99] Ruiz-Aceituno L, Rodríguez-Sánchez S, Ruiz-Matute AI, Ramos L, Soria AC, Sanz ML. Optimisation of a biotechnological procedure for selective fractionation of bioactive inositols in edible legume extracts. Journal of Science and Food Agriculture. 2013;**93**: 2797-2803

[100] Escott-Stump E, Mahan LK. Krause's Food, Nutrition and Diet Therapy. 10th ed. Philadelphia: WB Saunders Company; 2000. pp. 553-559

[101] Onwuliri VA, Obu JA. Lipids and other constituents of *Vigna unguiculata* and *Phaseolus vulgaris* grown in northern Nigeria. Food Chemistry. 2002;**78**:1-7

[102] Hashim N, Pongjata J. Vitamin A activity of rice-based weaning foods enriched with germinated cowpea flour, banana, pumpkin and milk powder. Malaysian Journal of Nutrition. 2000;**6**:65-73

[103] Kalogeropoulos N, Chiou A, Ioannou M, Karathanos VT, Hassapidou M, Andrikopoulos NK. Nutritional evaluation and bioactive microconstituents (phytosterols, tocopherols, polyphenols, triterpenic acids) in cooked dry legumes usually consumed in the Mediterranean countries. Food Chemistry. 2010;**121**:682-690

[104] Tsuda T, Makino Y, Kato H, Osawa T, Kawakishi S. Screening for antioxidative activity of edible pulses. Bioscience, Biotechnology, and Biochemistry. 1993;**57**:1606-1608

[105] Apea-Bah FB, Serem JC, Bester MJ, Duodu KG. Phenolic composition and antioxidant properties of koose, a deep-fat fried cowpea cake. Food Chemistry. 2017;**237**:247-256

[106] Manach C, Scalbert H, Morand C, Remesy C, Jimenez L. Polyphenols in foods and bioavailability. The American Journal. Clinical Nutrition. 2004;**79**(5):727-747

[107] Wu X, Beecher GR, Holden JM, Haytowitz DB, Gebhardt SE, Prior RL. Concentrations of anthocyanins in common foods in the United States and estimation of normal consumption. Journal of Agricultural and Food Chemistry. 2006;**54**(11):4069-4075

[108] Soobrattee MA, Neergheen VS, Luximon-ramma A, Aruomab OI, Bahorun T. Phenolics as potential antioxidant therapeutic agents: Mechanism and actions. Mutation Research. 2005;**579**(1-2):200-213

[109] McDougall GJ, Stewart D. The inhibitory effects of berry polyphenols on digestive enzymes. BioFactors. 2005;**23**(4):189-195