Introduction

Cowpea (Vigna unguiculata L. Walp) (Pasquet 1998) also known as black-eyed pea, bachapin bean, southern pea, crowder pea, China pea and cow gram is an herbaceous legume belonging to the family Fabaceae. It is well adapted to harsh arid climates and low fertile soils and more drought- and heat-tolerant than most of its legume relatives (Carvalho et al. 2017; Hall 2004; Timko and Singh 2008). Cowpea has been used for human consumption as well as an animal feed since antiquity. Cowpea plays a vital role in the livelihoods of millions of people in less developed countries of the tropics. For Africans, it plays a pivotal role in the economy and nutrition of their daily life (Houssou et al. 2010).
**Botany**

Cowpea is an annual herb with varying growth forms such as erect, semierect, prostrate, trailing, climbing or bushy. It has a taproot system with spreading lateral roots in surface soil. Cowpea roots establish a nitrogen-fixing symbiotic association with nodule-forming bacteria, rhizobia (Leite et al. 2017). The leaves are alternate and trifoliate except the first pair of leaves, which are basic and opposite. Leaves vary in shape from linear-lanceolate to ovate with petiole length of 5–25 cm. Stems are striate, smooth or slightly hairy. The flowers are white, yellowish, pale blue or violet and are born on racemose inflorescences at the ends of 2–20-cm-long peduncles. Pods are coiled, round, crescent or linear. Pods are usually 20–30 cm long and small seeded (Department of Agriculture Forestry and Fisheries, South Africa 2011) (Fig. 1).

**World Production and Trade**

Cowpea is originated and domesticated in Africa (Goncalves et al. 2016; Lazaridi et al. 2017; Richard 1847). Nowadays, it is widely grown in many other parts of the world as well such as Latin America, Europe, Asia and the United States (FAOSTAT 2019). However, Africa remains the leading producer of cowpea even today. According to FAOSTAT database, in 2017, total area under the cowpea production in the world was around 12.57 million ha, and the total production was 7.40 million MT. Africa is the largest producer in the world accounting more than 95% of the
world’s production of cowpea with Nigeria and Niger the leading producers in Africa. Asia, Americas and Europe contribute less compared to Africa for the world’s production as shown in Fig. 2 (FAO 2019). Cowpea is one of the most important agricultural exports from the West and Central Africa (Cowpea Storage Project: Profiles of Progress 2010). Of the developed countries, only the United States is a substantial producer and exporter of cowpea (Gómez 2004). It is reported that over the years, cowpea production increased more compared to other pulses. From 1981 to 2013, share in total pulse crop area increased from 5.7% to 14%, while its production share increased from 3 to 9% (Joshi and Rao 2017).

**Nutritional Value**

All parts of cowpea plant contain high nutritive value. The seeds (peas or grains) are rich source of good quality protein. The leaves also can be used as a vegetable, and the rest of the plant parts can be used as animal feed. Cowpea serves as an inexpensive source of good quality protein, especially for the poor population. It is a major source of protein in diet of many people in sub-Saharan Africa (Sebetha et al. 2015). Table 1 shows the amount of major nutrients present in cowpea grains.

Cowpea is considered as a nutrient-dense food with low energy density. Compared to cereal grains, cowpea has higher protein and carbohydrate contents with a relatively less fat content and a complementary amino acid pattern (Jayathilake et al. 2018). Cowpea seeds contain significant amount of essential amino acids such as leucine, lysine, phenylalanine, tyrosine, aspartate, glutamate and arginine. Most limiting amino acids in cowpea are S-containing amino acids such as methionine and cysteine, tryptophan and threonine (Farinu and Ingrao 1991; Jirapa et al. 2001), whereas cowpea is an excellent source of lysine (Iqbal et al. 2006).
Cowpea seeds contain relatively higher amount of lysine (3.5–7.9 g 16 g⁻¹ N) (Goncalves et al. 2016) compared to most cereal grains (2.3–4 g 16 g⁻¹ N) (Chavan et al. 1989). The bulk of the diet of the Africans mainly consists of starchy food made from cassava, yam, plantain and banana, millet, sorghum and maize. The incorporation of cowpea into these starchy diets could enhance the protein quality via synergistic effect of high protein and high lysine from cowpea and high methionine and high energy from the starchy foods. Thus, it ensures a nutritional security (Simion 2018).

Cowpea is also a good source of minerals and vitamins (Cruz and Aragão 2014), most importantly, vitamin C (Tresina and Mohan 2011; Etokakpan et al. 1983) and carotenoids (Hashim and Pongjata 2000). Calcium, zinc and iron are the important minerals found in cowpea seeds (Thangadurai 2005; Adebooye and Singh 2007; Goncalves et al. 2016). In addition to these basic nutrients, cowpea has soluble and insoluble dietary fibre and phytochemicals and thus possesses therapeutic potentials such as antidiabetic, anticancer, anti-hyperlipidemic, anti-inflammatory and antihypertensive properties (Jayathilake et al. 2018). Cowpea contains an interesting profile of polyphenols, especially the highly glycosylated flavan-3-ols, and the unusual predominance of quercetin glycosides.

### Antinutritional Factors

Even though cowpea is a very good source of protein and other nutrients, the presence of antinutritional factors brings about nutritional implications. Major antinutritional factors include tannin, protease inhibitors (trypsin inhibitors and chymotrypsin inhibitors), lectins, phytic acid, oxalic acid and flatulence-causing oligosaccharides (Goncalves et al. 2016; Khattab and Arntfield 2009). Intake of these substances over a long period of time is supposed to cause some adverse health effects because these compounds can interact with macro- and micronutrients, impairing their absorption during digestion, thus reducing the bioavailability of nutrients. However, in recent years, it has been suggested that they also have some beneficial health effects to

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Quantity on dry weight basis</th>
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<tbody>
<tr>
<td>Protein (%)</td>
<td>20–39</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>50–65</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>0.3–3</td>
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<tr>
<td>Fibre (%)</td>
<td>5–6.9</td>
</tr>
<tr>
<td>Minerals (%)</td>
<td>3–4</td>
</tr>
<tr>
<td>Essential amino acids (g/100 g protein)</td>
<td>27–33</td>
</tr>
</tbody>
</table>

Jayathilake et al. (2018), Goncalves et al. (2016), Kalogeropoulos et al. (2010), Ahenkora et al. (1998) and Prinyawiwatkul et al. (1996)
human (Abizari et al. 2012a; Goncalves et al. 2016; Singh et al. 2017). For instance, tannin and phytic acid possess anticancer properties. Phytic acid is believed to prevent colon cancer by reducing oxidative stress in the lumen of the intestinal tract by the iron chelating effect (Simion 2018).

Tannins are water-soluble phenolic compounds (molecular weights ranging between 500 and 3000 Da). Most of the tannins in cowpea are nonhydrolysable, also known as condensed tannins, flavolans or proanthocyanidins. They have the ability to interact with proteins and, in most cases, precipitate the proteins (Madsen and Brinch-Pedersen 2016). In addition, tannins lower digestibility of protein and carbohydrates via inhibiting the digestive enzymes and forming complexes with them (Khattab and Arntfield 2009; Jain et al. 2019). Tannins also can chelate ferric ions, thus interfering iron absorption (Madsen and Brinch-Pedersen 2016) and may lead to anaemia.

Lectins are carbohydrate-binding proteins of non-immune origin. Their binding with carbohydrates is reversible and highly specific. Thus, lectins may interfere with the digestion and absorption of carbohydrates. However, like other antinutritional factors found in cowpea, lectins also have been reported to possess antitumour activities (Lagarda-Diaz et al. 2017).

Cowpea seeds contain enzyme inhibitors such as protease inhibitors, trypsin and chymotrypsin inhibitors and amylase inhibitors. Trypsin inhibitors impair digestion and absorption of dietary protein by strongly inhibiting trypsin activity (Khattab and Arntfield 2009). Trypsin inhibitors belong to two families such as Bowman–Birk or the Kunitz families. Both are single-chain polypeptides; however, Bowman–Birk inhibitors are smaller (approximately 8 kDa) with seven disulphide bridges and two active domains for the inhibition of trypsin and/or chymotrypsin than Kunitz family (20 kDa), which has only two disulphide bridges. α-Amylase inhibitors interfere with the utilization of starch (Madsen and Brinch-Pedersen 2016).

Phytic acid (myo-inositol-(1,2,3,4,5,6)hexakisphosphate) is the major phosphorus storage compound in plants (Madsen and Brinch-Pedersen 2016). It has the ability to bind essential dietary minerals (zinc, iron, calcium, magnesium, copper and manganese), proteins and starch, thereby reducing their bioavailability (Khattab and Arntfield 2009).

Oxalic acid may form deleterious complexes with metal ions, e.g. calcium oxalate causing renal damage (Maina et al. 2015). High consumption of these compounds leads to flatulence and osmotic effect and interferes with digestion and absorption of other nutrients (Martinez-Villaluenga et al. 2008).

The presence of the α-galactosides such as raffinose, stachyose and verbascose is also reported to have adverse effects on nutritional value of the cowpea (Khattab and Arntfield 2009). α-Galactosides withstand the digestion in the human gastrointestinal tract due to lack of secretion of α-galactosidases. In the caecum, undigested α-galactosides undergo fermentation by anaerobic microflora composed mainly of Bifidobacterium, Bacteroides, Fusobacterium and Clostridium spp. Fermentation also leads to the formation of various gases such as hydrogen, carbon dioxide and methane and short-chain fatty acids such as acetate, butyrate and propionate causing flatulence (Madodé et al. 2013).
Ingestion of large amount of α-galactosides usually leads to flatulence in human and monogastric animals. Accumulation of flatus in the intestinal tract results in discomfort, abdominal rumblings, cramps, pain and diarrhoea (Martinez-Villaluenga et al. 2008). However, these flatulence-causing compounds are reported to reduce the risk of colon cancer and cardiovascular diseases in humans (Madodé et al. 2013). α-Galactosides are also reported to have beneficial effect on human health as they can stimulate the growth and activity of living Bifidobacterium and Lactobacillus in the human colon (prebiotic effect).

Various processing approaches such as soaking, germination, pressure-cooking, fermentation, enzyme treatment and genetic modification of the plant can be used to destroy these antinutritional components (Martinez-Villaluenga et al. 2008).

**Postharvest Processing**

Postharvest processing of cowpea aims to improve the quality of the grains while minimizing the losses due to insect and other pest infestations and physiological changes. In addition, reducing the effect of antinutritional factors to improve the nutritional value of cowpea is aimed at most processing technologies. Primary postharvest operations include drying, husking, winnowing, separation and storage, whereas secondary processing techniques include soaking, germination, fermentation, frying, milling, cooking and roasting (Subuola et al. 2012; Goncalves et al. 2016). Some conventional methods of postharvest storage and processing techniques have been replaced by new improved technologies. Besides antinutritional factors, consumption of cowpea is also confronted by some other issues such as beany flavour, flatulence and a long cooking time (Goncalves et al. 2016). Thus, cowpea requires extensive processing for their optimal utilization in the diet.

**Drying**

The pods are usually ready to harvest 60–120 days after planting. Pods should be harvested when 95% in one accession have turned yellowish brown (Dumet et al. 2008). During harvesting, cowpea grains have around 20% moisture. In order to prevent spoilage during storage, the moisture content of the grains should be reduced to between 8 and 12% depending on the intended duration of storage. The grains from pods are removed by hands or mechanically. Sometimes, pods are steeped in water for hours (2–8 h) or treated with oil before sundrying in order to facilitate dehusking process. Sundrying is the conventional method of drying.
Hulling, Winnowing and Splitting

Hulling can be performed by dry method or wet method. Dry method is traditionally practiced in African and Asian countries which involves pounding of the dried grains in mortar with pestles or in hand-operated wooden or stone shellers or power-operated shellers and abrasive hulling machines. Wet grinding process involves conditioning the grain by soaking of the grains before drying. Conditioning techniques through moisture adjustment facilitates easy husking (Department of Agriculture Forestry and Fisheries 2011). The separated husks are removed from the cotyledons by winnowing manually, which is time consuming and laborious. In order to overcome this problem, improved abrasive hulling machines have been developed.

Storage

After harvest, grains are dried, sorted and stored. The storage life of cowpea depends on its moisture content. The lower the moisture content, the better the quality of seeds in storage. In developed countries cold storage is commonly practiced. It is reported that exposure to −18 °C for 6–24 h can reduce the number of pests by more than 99%. If the grain storage is meant for short term, moisture content of around 12% or less is recommended. However, for long-term storage, it should be reduced to 8–9% (Department of Agriculture Forestry and Fisheries 2011).

The major problem with cowpea after harvest is the high susceptibility to insect infestation. The serious insect pest causing major economic loss during storage of cowpea is the cowpea weevil, Callosobruchus maculatus (Coleoptera: Bruchidae) (Tiroesele et al. 2015). Thus, appropriate measures should be considered to minimize the losses from insect attack.

During the 1980s, neem oil was widely used to minimize the losses from insect pests in small scale. This method had some advantages such as non-toxic and easily available. However, the use of neem oil was discouraged because of difficulties in extraction and imparted bitter taste to the grains (Gómez 2004). In order to reduce the losses during storage, various control techniques are being used since a long time ago, and some new techniques have been developed. Main control method is the application of chemicals as insecticides. However, it may not be feasible for small-scale farmers due to cost and some technical reasons. Since insecticides have negative impact on humans, environment as well as non-target organisms, there is a need to develop new techniques to overcome these problems. The use of some natural plant products (e.g. garlic and peppermint) which have the ability to produce odours that repel weevils can be used effectively (Tiroesele et al. 2015).

Traditionally, sacks and bamboo baskets have been used extensively to store the cowpea. However, in order to increase the storage period by many months without pest attack, in 2007, Purdue University research team and Bill & Melinda Gates Foundation introduced a new inexpensive packaging called triple-layer bag to
African farmers as a simple solution to protect cowpea from losses during storage. It was named as the Purdue Improved Cowpea Storage (PICS) bag. It is made from two inner high-density polyethylene plastic bags and an outer nylon sack which provide an airtight seal for long-term, pest-free storage. PICS bags addressed the cowpea storage problems without the use of chemicals (Cowpea Storage Project: Profiles of Progress 2010).

**Destroying the Antinutritional Factors**

Removal of antinutrients in order to improve nutritional quality is necessary for an optimal utilization of cowpea in human nutrition (Preet and Punia 2000). Different processing methods such as dehulling, soaking, low and high pressure-cooking, fermentation and germination can help improve the nutritional quality of food legumes by destroying antinutritional factors to various extents (Khattab and Arntfield 2009; Mubarak 2005). In addition to these processing approaches, breeding techniques also can be used to reduce the amount of antinutritional factors. However, since these compounds are reported to have some beneficial roles in the plant, their manipulation via genetic means should consider their positive roles as well in plants (Simion 2018).

**Cooking**

Heat processing is as an effective means of inactivating the heat-labile antinutritional factors such as enzyme inhibitors and lectins found in legumes (Akande and Fabiyi 2010). Various cooking methods such as boiling, pressure-cooking, roasting and microwave cooking are reported to reduce the level of antinutritional factors. Several authors have reported that moist heating is more effective than dry heating to inactivate antinutritional factors (Khattab and Arntfield 2009; Akande and Fabiyi 2010). The cooking of pre-soaked grains appeared to be the most effective method for reducing trypsin inhibitor activity (Jain et al. 2019). After cooking in boiling in water, the cooking water may be discarded to reduce the amount of antinutritional compounds; however, other soluble compounds with essential nutritional value also could be removed.

A study has been carried out to determine the effects of cooking and soaking methods on α-amylase inhibitors in cowpea (Piergiovanni and Gatta 1994). Boiling in distilled water and cooking in microwave oven were found to be ineffective, whilst autoclaving was effective in reducing the amount of α-amylase inhibitors. Soaking in alkaline solutions was more effective than soaking in distilled water. Boiling of soaked cowpea seeds gave pronounced effect in the reduction of α-amylase inhibitor.
**Soaking**

Some antinutritional factors such as α-galactosides and tannins are water soluble. Thus, soaking of grains in water or saline solutions and discarding the soaking solution will remove most of the water-soluble antinutritional factors (Martinez-Villaluenga et al. 2008).

**Fermentation**

Fermentation has been reported to reduce the antinutritional factors. The fermentation process could be natural (by the microorganism present in the seed) or induced (using a microbial culture) (Martinez-Villaluenga et al. 2008). Phytate content of the cowpea could be reduced during fermentation by endogenous phytase enzyme or by microorganisms such as yeast (Martinez-Villaluenga et al. 2008; Khattab and Arntfield 2009). However, Madodé et al. (2013) have reported that in vivo fermentability index of fermented cowpeas is significantly lower than that of traditionally processed (dehulled, soaked and boiled) cowpeas.

**Decortication or Dehulling**

Tannins are primarily located in seed coat of cowpea. Thus dehulling of seed can decrease the tannin content of cowpea and improves their nutritional quality. It is reported that dehulling can reduce the tannin content by about 68–99%. For instance, a study reported that decortication significantly reduced tannin content by 85% (Jain et al. 2019).

**Germination**

Germination is an important traditional processing method practiced before cooking of legumes. Reductions in tannin content of cowpea during germination could be attributed to presence and activity of polyphenol oxidase and enzymatic hydrolysis (Jain et al. 2019). Germination causes breakdown of certain complex compounds into simple compounds, transport of simple compounds to the endosperm and the synthesis of new materials from the breakdown products. During seed germination, storage proteins are hydrolysed, and the amino acids and complex polysaccharides are broken down into simple sugars. Phytic acid is hydrolysed by phytase resulting in the formation of available phosphorus (Akande and Fabiyi 2010).
Product Development

In the present context, there is a tendency of increasing the diversity of foods consumed. A plethora of factors such as changing lifestyles, development of new technologies, changing consumer demands and increasing consumer awareness on healthy foods lead to the rising demand for diverse food products with good nutritional value. Thus, for the food sectors, efforts on new food product development become inevitable.

Preparation of Cowpea

Cowpea is prepared for consumption as whole grain, split or ground forms. Dry grain can be consumed as boiled, fried or steamed in different preparations such as salads, snacks, breakfast cereals and baked goods. Cowpea can play an important role as a functional ingredient in such products, especially with the growing interest in high plant protein diets and ‘ancient grains’. Fresh seeds are often served boiled, as well as being consumed fried or fresh (Carvalho et al. 2017; Jayathilake et al. 2018). The seeds can also be cooked with meat, tomatoes and onions into a thick soup and eaten with pancake and bread (Sebetha et al. 2015). Dry mature seeds are also suitable for boiling and canning (Carvalho et al. 2017).

Since cowpea serves as the main protein source for the Africans, a variety of local preparations are prepared and consumed by Africans. Madodé and colleagues did a survey on local cowpea preparations available in Africa, and they have reported them with their nutritional composition (Madodé et al. 2011). According to them approximately 90% of the preparations are prepared using seeds, and the remaining prepared using leaves. Typical processing of cowpea includes steeping, dehulling, whipping, milling, and cooking. Seeds are prepared either alone or in combination with cereals, roots and tubers and/or cooking oils and seasonings such as salt, pepper and roasted shrimp (Madodé et al. 2011).

Preparations Based on Cowpea Grains

Seeds are cooked in different ways such as boiling, roasting and frying or combination of these methods. Usually seasonings are added to enrich the sensory qualities. Cooking raw seeds is usually time-consuming because of high calcium content, making the seeds hard. However, soaking (steeping) overnight in water is usually practiced to shorten the cooking time. Soaking is also helpful in minimizing antinutritional factors. Addition of sodium bicarbonate during cooking is also used to reduce the cooking time. In Africa, Kanwu, a kind of rock salt containing carbonate and bicarbonate of minerals such as Ca, Na and Fe, is used as softener (tenderizer).
Cooking in 0.05–0.1% of Kanwu can reduce the cooking time to a significant level during open pan boiling. The combination of pressure-cooking with a tenderizer can further reduce the cooking time (Madodé et al. 2011).

Cowpea fritter or snack dish, namely, Ata (Benin), Akara (Nigeria) or Koose (Ghana), is produced using a combination of processing methods. It is traditionally made by steeping and wet-dehulling (manually or mechanically) followed by grinding the dehulled seeds into a batter that is whipped to incorporate air. This dough is seasoned and deep-fat fried. This product takes at least a day to prepare, in order to allow the cowpea to soak and the batter to rest.

Doco or Ata-doco is a fried product similar to Ata. Whole or dry-sieved cowpea flour is whipped and deep-fried. Doco is cooled and fried a second time to obtain hard and dry fritters called Ataclè, which are immersed in oil for preservation. Ata, Doco and Ataclè are commonly consumed as a side dish with porridges, yam (Dioscorea sp.) or sweet potato (Ipomoea batatas) fries.

Yoyoue is a kind of oily flour. Cleaned seeds are roasted, seasoned, ground and finally deep-fried in cooking oil. Magni-magni, Lèlè or Alèlè (Benin), Moinmoin (Nigeria) or Koki (Cameroon) is a steamed product. Seeds are steeped, wet-dehulled, ground with seasonings to taste, whipped, mixed with palm oil and salt and finally wrapped in banana leaves for steaming.

In Ghana, cowpea flour is used to make a variety of items such as cowpea straw, cowpea pie, fried cowpea paste, cowpea porridge, cowpea twisted cake, stew, cowpea cutlet, cowpea pancake, cowpea chips, cowpea rock buns, cowpea pudding, cowpea doughnuts, cowpea biscuits, etc. (Gómez 2004).

Cowpea soup is another preparation based mainly on seeds. To prepare this soup, seeds are washed, soaked, dehulled, boiled, mashed and sieved. The sieved seeds are then cooked with palm oil along with other ingredients such as pepper, spices and seasoning with or without fresh or dried fish to taste to produce Gbegiri. It is eaten with reconstituted yam flour product Amala (Subuola et al. 2012).

**Cowpea Preparations Mixed with Cereals**

Cowpea preparations can be prepared by mixing with cereals such as rice and maize. Atassi (Benin) or Waakye (Ghana) is a product prepared by cooking parboiled seeds mixed with cleaned rice (usually at the ratio of cowpea/rice, 2–3).

Atchonkouin, Kossibobo, Adalou or Aibli is a combination of cowpea and maize. Maize is parboiled and then boiled together with cowpea. Abla is a paste made from maize (about 30%), cowpea (about 30%) and crude palm fruit extract or refined palm oil (about 40%). To prepare this, fine cowpea flour is mixed with fine maize flour and potash filtrate and blended with palm oil to obtain a homogeneous dough, which is wrapped in banana leaves and steam-cooked. By replacing cowpea flour by dehulled seeds, Kowe is obtained.

Cowpea pie is used as main dish and it is prepared by incorporating rice. Cowpea and rice are cooked until they become very soft and are mashed together. To this...
mixture gravy with seasonings is added and baked. *Adalu* is a mixture of cowpeas and maize. It is also called *NiébéetMaïs* or, in English, ‘black-eyed peas and corn’. In Africa, it is usually made with dried cowpeas and either fresh or dried maize. It can also be adapted to use canned or frozen black-eyed peas and corn.

**Cowpea Preparations Based on Mixtures with Roots or Tubers.**

A type of *Magni-magni* processed without oil and seasonings is *Toubani*. Cowpea is partially dehulled, whipped and moulded in recycled tins or leaves before steam cooking. Yam (*Dioscorea* sp.) or cassava (*Manihot esculenta*) flour is usually added as a binder along with sodium bicarbonate.

Cowpea can also be used to enhance the acceptability of water yam (*Dioscorea alata*), which is inappropriate for making pounded yam. *Dioscorea alata* tubers are grated, mixed with cowpea flour (5% of the grated yams’ weight), whipped and deep-fried to produce a fritter named *Alounganta*. *Tche* is a kind of *Abobo* obtained by boiling seeds with peeled and sliced yam.

**Products Prepared by Mixing with Other Products**

*Akpada* is a very thick cowpea sauce. A thick tomato sauce is prepared, to which cowpea flour is added, mixed and cooked together. Red-Red is a popular dish in Ghana made from cowpeas prepared by the combination of red pepper and red palm oil. The Red-Red cowpeas stew is usually served with fried plantains.

Nowadays, breakfast cereals as convenient and energy-dense food play a vital role in daily diets of the people of most countries. The typical breakfast cereals are rich in carbohydrates and fibre. There is a potential to prepare breakfast cereals enriched with cowpea (sprouted or non-sprouted) using extrusion technique (Marengo et al. 2017).

**Cowpea Protein Isolates**

Since cowpea is a rich source of proteins, functional properties of proteins can be exploited. Functional proteins of cowpea can be extracted using different methods and utilized in various products. Proteins in the foods can interact directly or indirectly with other components in the foods and change the properties of foods due to their functional properties. Cowpea protein isolates can be used as a food additive such as emulsifier, texturizer, stabilizer and fat replacer or as a supplement to enrich the nutrient content of other food stuffs. For instance, protein isolates from cowpea can be utilized to improve the properties of gluten-free rice muffins (Shevkani et al. 2017).
Cowpea protein isolate can also be incorporated with food products, especially cereal-based products, which contain lysine as a limiting amino acid and are rich in methionine (Frota et al. 2017). Protein isolates can also be used to make textured vegetable proteins. Textured vegetable protein made from soybean is popular among vegetarians in most of the tropical countries. However, textured vegetable proteins made using cowpea proteins are not available in the market so far.

**Cowpea-Fortified Foods**

Fortification is the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals in a food, so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health (Allen et al. 2006). Cowpea is rich in some vitamins (vitamin C and carotenoids) and minerals (such as calcium, zinc and iron). Thus, it is possible to fortify other foods which are lacking in those particular micronutrients with cowpea. However, consideration should be given to the elimination of antinutritional factors which limit the bioavailability of these micronutrients.

A study has been carried out to develop a recipe for an enriched cheese bread with whole biofortified cowpea flour; its chemical composition and consumer acceptance were evaluated. Cookies fortified with defatted cowpea flour (10% of wheat flour replaced by cowpea flour) contained increased Ca content in addition to increased crude fibre, protein and ash contents (Cavalcante et al. 2016).

**Fortified Cowpea Foods**

Moreover, cowpea itself can also be fortified to enrich its micronutrient content. For example, a study has been carried out to fortify cowpea meal with NaFeEDTA, and the results indicated that fortification of cowpea flour with NaFeEDTA overcomes the combined inhibitory effect of phytic acid and polyphenols and is effective in reducing the prevalence of iron deficiency and iron deficiency anaemia (Abizari et al. 2012b).

**Weaning Foods**

Weaning foods are introduced to the infants during the period between breast-feeding and total solid food intake. Hence, easily digestible nutritious and energy-dense foods should be given during the weaning period. Malting is one of the simple traditional techniques to improve the nutritional quality as well as digestibility of cereals and legumes. Malting process consists of three stages such as steeping,
germination and drying. During germination, endogenous enzymes, such as α-amylase and α-glucosidase, limit dextrinase, and proteases hydrolyse the polysaccharides into simple sugars (Gupta et al. 2010). In addition, several other favourable changes such as enhanced flavour and increase in essential amino acids (lysine, methionine and tryptophan) and vitamins (riboflavin, niacin and ascorbic acid) occur during germination (Baranwal 2017). Thus, malting can be taken advantage of in the development of weaning foods.

Steeping in water followed by germination for 24–48 h at 25–28 °C can be used as malting conditions. Most of the commercially available weaning foods are extruded or roller-dried which need high capital. Malting is a very simple and inexpensive technique; thus, it could be easily adapted in developing countries. Malted cereals and legumes can be used in weaning foods. For example, weaning foods can be prepared by mixing malted sorghum, green gram, black gram and steamed or germinated cowpea. It is reported that in vitro protein quality and starch digestibility of cowpea protein can be improved through germination (Jirapa et al. 2001). Thus, it is necessary to determine the optimum conditions for malting to be used in weaning foods with good nutritional and sensory characteristics.

In a study to evaluate the possibility of processing a ready-to-eat nutrient-rich weaning food for infants from cooking banana fortified with cowpea and peanut using in vitro digestibility, it is reported that it is feasible to produce precooked weaning food which has the potential to meet the nutritional needs of an infant (Bassey et al. 2013). In order to get more balanced nutritious weaning food from cowpea, other grains such as mung bean, green gram, rice, etc. could be incorporated.

**Future Trends in Processing and Product Development**

There has been a mounting interest in the use of legumes as a balanced source of nutrient during the past few years. Among legumes, cowpea is considered an important crop because of its wide adaptation to agroclimatic conditions and its nutritional value, importantly, protein at low cost. However, cowpea remains an underexploited crop, and it has received relatively little attention from a research standpoint.

There are some limiting factors for the dietary utilization of cowpea. These include the presence of antinutritional and flatulence-causing factors as well as the long duration of cooking because of hard seed coat. Thus, cowpea requires further developments in processing alternatives allowing the effective utilization of nutrients in cowpea with minimal impact on human health. In this scenario, much focus should be given to the intense research efforts in order to expand the cowpea preparations in new forms with potential contribution to human nutrition. In order to develop new products with good nutritional value, a thorough understanding of the composition of the cowpea is crucial. The development of innovative cowpea preparations and cowpea-enriched preparations is a promising way to exploit the full potential of cowpea as a good nutritional source.
Cowpea grains are reported to contain an array of polyphenols, which exert beneficial health effects. Polyphenols are concentrated in the seed coat; thus, processing technologies that remove the seed coat will almost entirely eliminate the polyphenols, besides eliminating valuable dietary fibre. However, thermal processes such as moist heat cooking used to prepare cowpea preparations reported to have limited effect on the profile of these compounds; thus their benefits are likely retained in such products (Awika and Duodu 2017).

Extrusion cooking is gaining popularity for production of expanded snacks, because there is a huge demand for healthy and nutritious ready-to-eat products from all age groups of consumer all over the world. Extrusion cooking can be applied in cowpea processing in order to produce variety of value-added food products from cowpea with good nutritional value. It has been reported that in vitro protein digestibility of extruded cowpea is significantly higher than that of whole raw cowpea (Jakkanwar et al. 2018). High-protein instant porridge can be prepared using extrusion technology from cowpea incorporated with other grains such as sorghum (Pelembe et al. 2002). In addition, there is a potential to produce textured vegetable proteins from cowpea protein isolates using extrusion cooking. Thus, attempts should be made to produce textured vegetable proteins from cowpea in order to ensure the availability of variety of cowpea-based products and make efficient utilization of cowpea.

Cowpea research has been underway in some African countries for many years. In Nigeria, the Federal Department of Agricultural Research, the Institute for Agricultural Research and Training (IAR&T) at Ibadan, the University of Ife and the Institute of Agricultural Research (IAR) and Centre National de Recherches Agronomiques (CNRA) in Senegal have started cowpea research in the 1960s (Boukar et al. 2018). However, further researches on breeding are needed to exploit the valuable genes to improve cowpea yield and quality. The general target of most breeding programmes is to develop varieties with high yield, improved adaptation to different agroecological zones and improved tolerance to pest attack and other adverse conditions. However, researches on breeding to improve nutritional quality of cowpea grains are lacking. Thus, more emphasis should be given to improve the nutritional value of the cowpea via reducing the antinutritional factors and/or increasing the amounts of essential amino acids and other nutrient contents.

Further research is necessary to evaluate the opportunities to efficiently use cowpea to help protect against nutritional deficiency diseases and economy of the peasant farmers in Africa as well as other developing countries, which eventually could play a role in global food supply helping towards the food and nutritional security.

References


