Chapter 3. Cowpea (*Vigna unguiculata*)

*This chapter deals with the composition of cowpea (*Vigna unguiculata*). It contains elements that can be used in a comparative approach as part of a safety assessment of foods and feeds derived from new varieties. Background is given on cowpea description, global production (predominantly in Africa and South America), uses for human and animal consumption, and processing into many products. Appropriate varietal comparators and characteristics screened by breeders are presented. Nutrients in whole grain, leaves and aerial parts of the cowpea plant, as well as main anti-nutrients and other constituents, are then detailed. The final sections suggest key products and constituents for analysis of new cowpea varieties for food use and for feed use.*

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Background

General description of cowpea Vigna unguiculata *L.*

The cowpea (*Vigna unguiculata* (L.) Walp.) is an annual herbaceous legume (family Fabaceae) grown predominantly in Africa and is an important staple crop providing an affordable source of protein (Muranaka et al., 2016). The cowpea has a number of common names, including Black-eye pea, Black-eye bean, Crowder pea and Southern pea, frijol caupí and feijão-caupí. Yardlong bean or asparagus bean are common names for the related subspecies, *sesquipedalis*, the pods of which are a popular green vegetable in the People's Republic of China, South and South-East Asia.

Cowpeas are classified into five cultivar-groups: *biflora*, *melanophthalmus*, *sesquipedalis*, *textilis* and *unguiculata* (Pasquet, 2000).

Among the cultivated crop plants, the cowpea is one of the most variable species in terms of its plant growth, morphology, maturity and grain[1] types (Singh, 2014). The cowpea has a long taproot and adaptation mechanisms such as turning the leaves upwards to prevent them from becoming too hot and closing the stomata that help give it drought tolerance. As a legume crop, the cowpea fixes atmospheric nitrogen through symbiotic interactions with soil rhizobia (Sarr, Fujimoto and Yamakawa, 2015).

The cowpea corolla is yellowish-white to violet-white (Figure 3.1, Panel A), the pods occur in pairs and the leaves are trifoliate with oval leaflets (Figure 3.1, Panel B). Cultivated cowpeas are mostly indeterminate and some have the potential to produce multiple flushes of flowers (Gwathmey, Hall and Madore, 1992). Cowpeas are also diverse in their grain appearance, including the colour of the seed coat, seed size and eye colour (Figure 3.1, Panel C) (Carnovale, Lugaro and Marconi, 1991; Farinu and Ingrao, 1991; Kochhar, Walker and Pike, 1988; Gerrano, Jansen van Rensburg and Adebola, 2017a).

The cowpea was first domesticated in Africa between 1700 to 1500 before the Current Era (Singh, 2014) and all cultivated varieties grown in the world today originated from East and West Africa (Xiong et al., 2016). Despite the considerable morphological diversity, limited genetic diversity occurs among cultivated cowpea varieties owing to a single domestication event that has given rise to all cultivated varieties (Fang et al., 2007; Pasquet, 2000; 1999).

The present-day importance of the cowpea as an agricultural plant stems largely from its use as a short season protein-rich grain crop for human or animal consumption. In the African marketplace, harvested cowpea grain provides a cost-effective substitute for the less affordable foods from livestock and fish. Cowpea leaves can be harvested for direct use as needed during times of food scarcity while end of season collection of above-ground biomass after harvest provides valuable feedstock as fodder hay either for direct use or as a transportable commodity for sale or barter (Kristjanson et al, 2001; Hollinger and Staatz, 2015).

Further description on the cowpea taxonomy, plant, geographic distributions, habitats, crop production, centres of origin and diversity, reproductive biology, genetics and genome mapping, species/sub-species hybridisation and introgression, ecology, common pests and pathogens, and biotechnological developments can be found in the OECD Consensus Document on the Biology of cowpea (OECD, 2015).

Figure 3.1. Some key organs from the cowpea

A) flower; B) green pods and leaves; C) display of seed variety from different cultivars

Source: Courtesy of Carl Davies, CSIRO and Jeff Ehlers, University of California.

Production

Cowpeas are cultivated predominantly in Africa (Table 3.1) and are grown for food, fodder and green manure. Cowpea production has expanded in the world over the past decades (Figure 3.2). In 2017, over 87% of the crop was produced in Africa (Table 3.1). In South America, Brazil showed a recent increase in cowpea cultivation, placing the country in third place in terms of global area and production. According to FAOSTAT (2019) and the Brazilian National Supply Company (CONAB, 2018), the ten top producers of dry cowpeas in 2017 were Nigeria (3 410 thousand tonnes (kt)), Niger (1 959 kt), Brazil (749 kt), Burkina Faso (604 kt), the United Republic of Tanzania (201 kt), Cameroon (198 kt), Myanmar (179 kt), Kenya (146 kt), Mali (145 kt) and Sudan (130 kt).

Table 3.1. Global and regional production of the cowpea in 2017

Dry, thousand tonnes

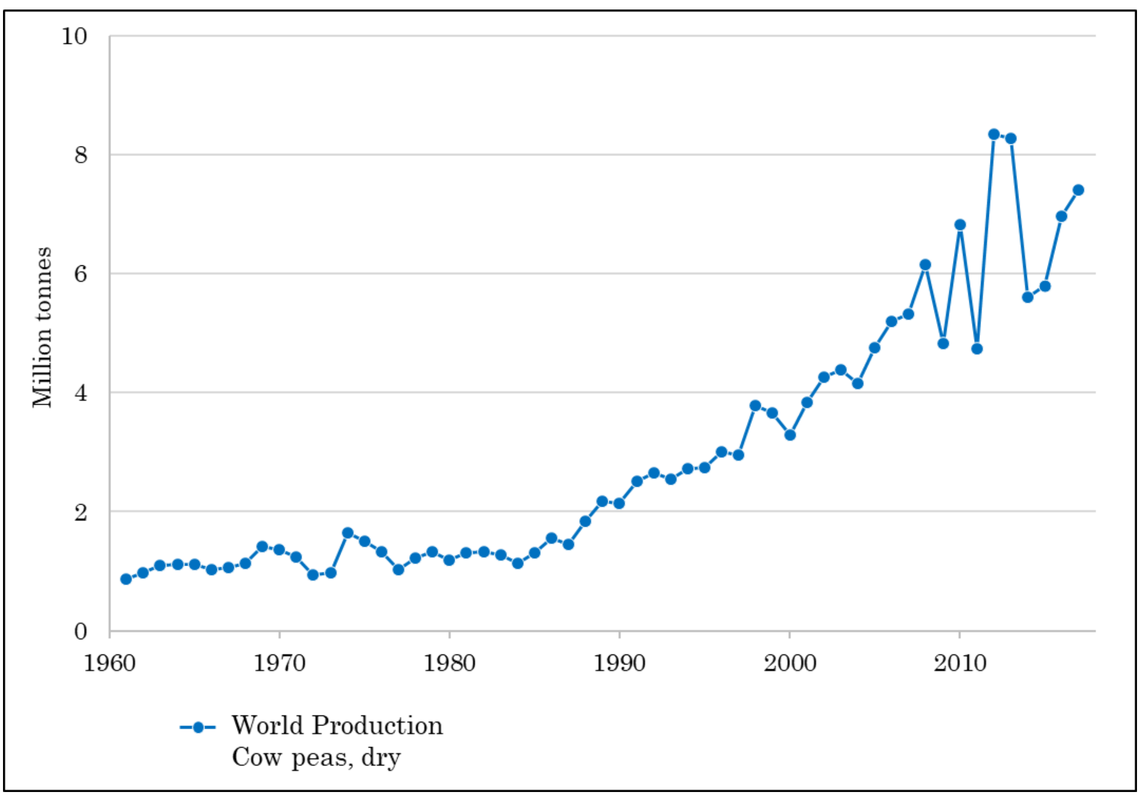
Region	Production
Africa	7 107
Americas	819*
Asia	204
Europe	27
Oceania	(-)
World	**8 157***

Notes: * FAOSTAT (2019) with the addition of Brazil production data, 749 kt in 2017/18 reported by the National Supply Company CONAB (2018).

Sources: FAOSTAT (2019), "Production – Crops – Production quantity – Cow peas, dry – 2017", http://www.fao.org/faostat/en/ (accessed on 10 July 2019), Aggregate may include official, semi-official, estimated or calculated data;
CONAB (2018), *Observatório Agrícola – Acompanhamento da safra brasileira de grãos*, http://www.conab.gov.br/OlalaCMS/uploads/arquivos/18_03_13_14_15_33_grao_marco_2018.pdf (accessed on 21 March 2018).

Figure 3.2. Increasing worldwide production of the cowpea, 1961–2017

Dry, million tonnes



Notes: This figure highlights the increasing trend in the cowpea's world production; the amounts for recent years, however, might be underestimated (e.g. Brazil data missing from the totals).
Source: FAOSTAT (2019), "World Production – Cow peas, dry – Years 1960-2017", http://www.fao.org/faostat/en/ (accessed on 10 July 2019), Aggregate may include official, semi-official, estimated or calculated data.

The cowpea is the most economically important indigenous African legume crop (Langyintuo et al., 2003). The majority of cowpea exports and imports occur within Africa for human consumption. It is actively traded from West to Central Africa because of the comparative advantage that drier areas of West Africa have in growing cowpea. Niger, Burkina Faso, Benin, Mali, Cameroon, Chad and Senegal are net exporters; Nigeria, Ghana, Togo, Côte d'Ivoire, Gabon, and Mauritania are net importers (Langyintuo et al., 2003). Since 2008, Brazil has exported the brown-eyed white commercial type to countries such as India, Israel, Pakistan, Turkey, the United Arab Emirates, Singapore, Indonesia, Nepal, Viet Nam, Portugal, and Italy (Aguiar, 2016; Freire Filho et al., 2017).

Uses

For human consumption, the cowpea is mainly grown for grain (dry and fresh) and sometimes for fresh pods in West Africa, India, and South America, while also grown for leaves in East Africa. It is an underused legume crop with a high potential for food and nutritional security in South Africa and produced for grain, immature green pods and fresh leaves due to its nutritional composition (Gerrano et al., 2015a; 2017a). The cowpea can be used to produce a large range of dishes and snacks (Uzogara and Ofuya, 1992; Asif et al., 2013) (Table 3.2).

Table 3.2. Examples of food uses of cowpea

Cowpea food	Description	Uses
Akara	Fried cowpea ball	Breakfast foods and snacks
Moin-moin	Steamed cowpea paste	Lunch and dinner foods
Ewa-ibji	Boiled whole cowpea	Lunch and dinner foods
Danwake	Boiled dehulled cowpea	Lunch and dinner foods
Gbegiri	Cowpea soup	Appetizers
Adayi	Cowpea purée	Pureed baby foods
Cowpea spread	Boiled mashed cowpeas with fat and seasoning	Spread on bread and yam
Roasted cowpea	Flavoured roasted cowpea	Snack food
Cowpea bread	Local bread made with cereal flour and cowpea flour	Breakfast, lunch and snack food
Cowpea cake	Cowpea used as an ingredient in cakes and pies	Breakfast and snack food
Rice and beans jollof	Boiled rice and boiled cowpeas	Food for adults
Akidi-na-oka	Dish of maize, cowpea	Food for adults
Cowpea sorghum dish	Boiled sorghum and cowpea	Food for adult
Cowpea plantain potage	Boiled cowpea and plantain	Food for adult
Cowpea yam potage	Boiled cowpea and yam	Food for adult
Cowpea weaning food	Dehulled, boiled cowpea supplemented to cereal-based infant foods	Infants, children food

Source: Asif, M. et al. (2013), "Application and opportunities of pulses in food system: A review", http://www.sciencedirect.com/science/article/pii/0308814690900456/pdf?md5=079b319a1346fef268dee5b0ccf323a2&pid=1-s2.0-0308814690900456-main.pdf.

The consumption of the cowpea as a dietary staple in West Africa over millennia has produced extensive and varied culinary practices and many individual foods and dishes. Cowpea consumption in West Africa has led to a culinary practice that requires seed coat removal (also called decortication or dehulling). For example, the popular West African cowpea-based foods, such as *Akara* and *Moin-moin*, are decorticated (Phillips, 2012). Four popular dishes in Brazil include "*Baião de dois*", a mix of cowpea and rice, cooked together (Figure 3.3, Panel A); *Akara* or "*Acarajé*", fried cowpea ball (Figure 3.3, Panel B); *Abará*, fried cowpea and shrimp ball rolled in banana leaves (Figure 3.3, Panel C), and "*Mugunzá*", a mix of cowpea, corn and pork meat (Figure 3.3, Panel D). In the United States, cowpeas are available to consumers as dry, canned or frozen grain (Phillips, 2012).

Consumer preferences for seed coat and eye colours vary from place to place and the cowpea variety can also affect food use (Table 3.3). For example, Ghanaian consumers pay a premium for black-eye whereas those in Cameroon discount black-eye. The most common preference for seed coat colour is white but, in some areas, consumers prefer red, brown or mottled grains. Up to nine different varieties may be on sale in a single domestic market (Langyintuo et al., 2003). In Brazil, the commercial varieties include Smooth White, Rough White, Smooth Brown, Evergreen, and Crowder (Freire Filho et al., 2017).

The cowpea is also utilised as fodder, fertiliser and as a quick-growing cover-crop and plays a particularly critical role in feeding animals during the dry season in many parts of West Africa (Uzogara and Ofuya, 1992; Singh and Tarawali, 1997). The haulms (stems) are a tradable commodity in fodder markets and the economic value of haulms has prompted cowpea breeders and livestock nutritionists to explore haulm fodder traits as additional selection and breeding criteria (Samireddypalle et al., 2017).

Short-duration spreading varieties are preferred for grain production and long-duration spreading varieties are preferred for fodder, the International Intitute of Tropical Agriculture (IITA) in collaboration with the International Livestock Research Institute (ILRI) have developed medium-maturing, semi-erect, dual-purpose varieties with higher grain and fodder yields and with enhanced fodder quality (Singh et al., 2003; Kristjanson et al., 2005; Samireddypalle et al., 2017). Similarly, Gerrano et al. (2015b) identified different cowpea genotypes that possess good vegetative traits and are also recommended for use as suitable parent lines when breeding for leaf or fodder production.

Table 3.3. Cowpea cultivars in Nigerian markets

Cultivar	Description	Food use
Black-eye variety	White seed coat and black hilum with tight-fitting seed coat	Boiled; Moin-moin and Akara after dehulling for paste production
Brown variety e.g. Ife brown	Brown seed coat and white hilum	Combination dishes with cereals, tubers, plantains and other legumes; not suitable for Akara and Moin-moin because of the brown colouration
White variety	White seed coat and white hilum	Paste products, e.g. Moin-moin and Akara

Source: Adapted from Uzogara and Ofuya (1992), "Processing and utilization of cowpeas in developing countries".

Figure 3.3. Examples of Brazilian (A-D) and Nigerian (E-H) cowpea dishes

Notes: F. Fried cowpea dough (called “*Akara*” in Igbo and Yoruba, “*Kosei*” in Hausa) in a bread roll.
G. “*Moin-moin*”, called cowpea or bean pudding in English, “*Olele*” in Yoruba, “*Alele*” in Hausa.
H. Bean (cowpea) soup, called “*Mian Wake*” in Hausa, “*Gbegiri*” in Yoruba.

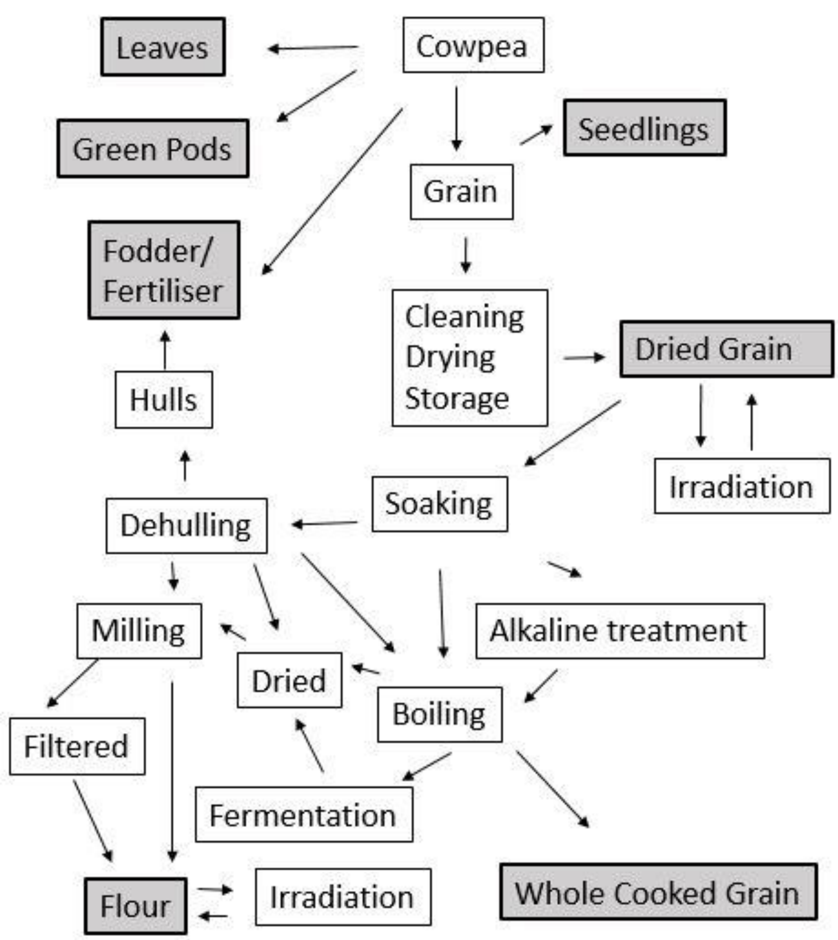
Sources: A. to D. Courtesy of Maurisrael de Moura Rocha, Embrapa; E. Courtesy of Mohammed Ishiyaku, IAR, Zaria; F. to H. Courtesy Umaru Abu, AATF.

Processing

Processing of cowpeas and legumes, in general, is essential to make them nutritious, nontoxic, palatable and acceptable. The cowpea is utilised either whole or decorticated or dehulled. It is decorticated by soaking in water (at room temperature) for about 30-60 min, and the seed coat removed by squeezing between the palms or by gentle abrasion using grinding stones. The seed coat is separated by subsequent filtration (Adebooye and Singh, 2007).

The constraints to maximum utilisation of cowpeas can be overcome by appropriate processing technology. For example, these techniques include dehulling, grinding, soaking, germination, fermentation, addition of salts, wet and dry heat treatments, cooking and roasting (Uzogara and Ofuya, 1992; Adebooye and Singh, 2007). Irradiation by gamma rays can also be used to sterilise cowpea flours and pastes but high levels of irradiation can reduce food quality (Abu et al., 2005). The most commonly used processing methods for cowpea products are presented in Figure 3.4.

Figure 3.4. Methods of processing for cowpea value-added products



Note: Shaded boxes represent end-use.

Sources: Adapted from Madode et al. (2013), "Enhancing the digestibility of cowpea (*Vigna unguiculata*) by traditional processing and fermentation" and Prinyawiwatkul et al. (1997), "Functional characteristics of cowpea (*Vigna unguiculata*) flour and starch as affected by soaking, boiling, and (…)" http://www.sciencedirect.com/science/article/pii/S0308814696002592/pdf?md5=072d9a708b842e2276c8b576a49b544c&pid=1-s2.0-S0308814696002592-main.pdf..

Soaking cowpeas prior to cooking softens the cotyledons and reduces the cooking time by over 30% (Uzogara and Ofuya, 1992). Reduced cooking time is needed for cowpea varieties with small grain size and a rough seed coat (Nielsen, Brandt and Singh, 1993). Seed coat removal results in faster cooking times, increased digestibility, better texture and appearance (Uzogara and Ofuya, 1992; Phillips, 2012). In Ghana and Nigeria, the cooking time of cowpeas is traditionally reduced by cooking them with a naturally-occurring alkaline rock-salt known as "kanwa" (Uzogara, Morton and Daniel, 1988).

Soaking and boiling of cowpeas is required to improve texture and reduce oligosaccharide levels to lessen the incidence of flatulence (Akinyele and Akinlosotu, 1991; Akpapunam and Achinewhu, 1985; Egounlety and Aworh, 2003; Madode et al., 2013; 2011; Onyenekwe, Njoku and Ameh, 2000; Phillips and McWatters, 1991; Prinyawiwatkul et al., 1996; Singh, 2014). Fermentation has also been used as a process to further reduce oligosaccharide levels (Akinyele and Akinlosotu, 1991; Akpapunam and Achinewhu, 1985; Madode et al., 2013; Prinyawiwatkul et al., 1997; Uzogara and Ofuya, 1992; Egounlety and Aworh, 2003).

The eating quality of milled cowpea products, particularly their texture, depends on the flour's composition, degree of grinding fineness and relative proportions of particles with different mesh grades, and cooking conditions (Uzogara and Ofuya, 1992; Yeung et al., 2009).

Appropriate comparators for testing new varieties

This document suggests parameters that cowpea breeders should measure when new cowpea varieties are produced. Measurement data from the new variety should preferably be compared to those obtained from the near-isogenic non-modified variety (or other existing varieties), where both have been grown and harvested under similar conditions.[2] The comparison can also be made between values obtained from other varieties described in the literature.

Critical components include key nutrients and anti-nutrients. Key nutrients are those components in cowpea that may have a substantial impact on the overall diet, including major constituents (proteins, fats and carbohydrates) and minor components (vitamins and minerals). Similarly, the levels of known anti-nutrients should be considered. As part of the comparative approach, selected plant metabolites, for which characteristic levels in the species are known, can be analysed as further indicators of the absence of unintended effects of the breeding strategy on metabolism.

Traditional characteristics screened by developers

The majority of cowpea production occurs under low input agriculture on small-scale farms in developing countries, and under such conditions, yield is mostly below its potential for the crop (Singh, 2014). Improving cowpea yields, nutritional quality, stress tolerance or resistance to pests and diseases are key objectives for various national and international breeding programmes[3] (OECD, 2015). The cowpea plant is attacked by pests during every stage of its life cycle, including storage. Pests include viruses, bacteria, fungi, aphids, flower thrips, pod borers, weevils, parasitic weeds and nematodes (Singh, 2014; IITA, Nigeria).

Breeders have developed varieties that are high yielding, early or medium maturing, have large seeds, altered seed coat texture/colour, enhanced cooking and nutritional aspects,[4] dual feed/fodder use and pest resistance. Due to the demand for cultivars that are suitable for fully mechanised cultivation, the cowpea plant architecture has been targeted for improvement, primarily to obtain erect plants and insertion of pods above the leaves (Figure 3.5) (Rocha, Damasceno-Silva and Menezes-Júnior, 2017).

Figure 3.5. Modern cowpea breeding to obtain erect plants with pods inserted above the leaves

Source: Courtesy of Maurisrael de Moura Rocha, Embrapa.

Nutrients

Composition of the cowpea – General points

Most of the nutrient composition data is based on cowpea whole grain, although there is a limited amount of data for dehulled grains, sprouted grains and leaves. Whole grains include the seed coat which represents 6% of grain dry matter (Aremu, 1990).

The cowpea is morphologically variable and adapted to different environments, resulting in a wide range of local varieties (OECD, 2015). The nutritional composition of cowpea is impacted by genetic characteristics, agro-climatic conditions, biotic stresses and postharvest management (Goncalves et al., 2016; Murdock et al., 2003; Oluwatosin, 1998; Silveira et al., 2001).

The cowpea is highly nutritious and has potential health benefits because of its high protein, high fibre and low glycaemic index, (Aguilera et al., 2013; Carnovale, Lugaro and Marconi, 1991; Siddhuraju and Becker, 2007; Sreerama, Sashikala and Pratape, 2012; Xiong, Yao and Li, 2013; Xu and Chang, 2012).

Constituents of the cowpea

Proximate composition, fibre, amino acids and fatty acids

The proximate composition of a large number of cowpea varieties is listed in Tables 3.4 and 3.5.

Carbohydrates and fibres

The cowpea contains a high proportion of carbohydrates, representing the majority of the dry weight of the grain, leaves, and sprouts (Tables 3.4 and 3.5). Eight sugars (simple carbohydrates) have been reported in the cowpea, namely, sucrose (11-19 g/kg), glucose (4-5 g/kg), fructose (1-2 g/kg), galactose (≤ 15 g/kg), maltose (≤ 11 g/kg); and three carbohydrates considered to be anti-nutrients, stachyose (17-60 g/kg), verbascose (6-13 g/kg), and raffinose (5-10 g/kg) (Goncalves et al., 2016).

The crude fibre (complex carbohydrates) content of whole cowpeas ranges from 2.5% to 32% of total dry matter (Table 3.4). The crude fibre content decreases when the seed coat is removed.

The means for total, insoluble and soluble dietary fibre of dehulled cowpeas reported by Khan et al. (2007) are 18.2%, 14.8%, and 3.3% of dry matter respectively. Total dietary fibre includes cellulose (6%), hemicellulose (3.9%), lignin (2%), and pectin (1.8%) (Khan et al., 2007).

Protein

The cowpea provides a source of protein (Boukar, Massawe and Muranaka, 2011) with the whole grain containing levels ranging from 16% to 31% (Table 3.4). The seed coat contains 12% protein (Aremu, 1990). Most of the cowpea grain proteins consist of globulins with lower levels of albumins, glutelins, and prolamins (Goncalves et al., 2016; Vasconcelos et al., 2010).

The amino acid composition of the cowpea is rich in lysine, leucine, arginine and other essential amino acids and can largely fulfil the essential amino acid requirements of a human diet. However, cowpeas are low in the sulphur amino acids (methionine and cysteine) compared to cereals and animal products and thus, for a balanced diet, cowpeas need to be supplemented with cereals or vegetables, meat and/or dairy products (Iqbal et al., 2006; Uzogara and Ofuya, 1992; Hussain and Basahy, 1998; FAO, 2004) (Tables 3.6 and 3.7).

Lipids/fatty acids

The lipid content of cowpea whole grain ranges from 0.5% to 3.9% (Table 3.4). The lipid profile of cowpea indicates a predominance of triglycerides (41.2% of total fat), followed by phospholipids (25.1% of total fat), monoglycerides (10.6% of total fat), free fatty acids (7.9% of total fat), diglycerides (7.8% of total fat), sterols (5.5% of total fat) and hydrocarbons and sterol esters (2.6% of total fat) (Goncalves et al., 2016). With respect to fatty acids, linoleic acid and palmitic acid predominate followed by oleic acid, stearic acid and linolenic acid (Thangadurai, 2005; Goncalves et al., 2016).

Minerals

Cowpeas are a source of essential minerals, calcium, magnesium, potassium, iron, zinc and phosphorus (Tables 3.8 and 3.9). Low availability of soil phosphorus is a primary constraint to cowpea production in developing countries (Burridge et al., 2016). Levels of grain phosphorous, potassium and manganese vary widely due to environmental conditions (Adebooye and Singh, 2007).

Most minerals are at higher concentrations in leaves (Gerrano et al., 2015a) and immature green pods (Gerrano, Jansen van Rensburg and Adebola, 2017b) compared to grain (Belane and Dakora, 2012; Madode et al., 2011). Some minerals are lost when the seed coats are removed (Table 3.8 vs. Table 3.9) (Mamiro et al., 2011).

Vitamins

Cowpeas are a source of thiamin and niacin, and also contain reasonable amounts of other water-soluble vitamins such as riboflavin (Table 3.10). Vegetative tissues including germinated grain tend to have higher levels of niacin, thiamin and riboflavin than grain (Nnanna and Phillips, 1989; Goncalves et al., 2016). Seed coat removal results in up to 30% loss in niacin content, while thiamin is reduced 41% by cooking (Nnanna and Phillips, 1989). Vitamin C values are higher in leaves than grains and increased by 4 to 38-fold after grains sprout (Devi, Kushwaha and Kumar, 2015; Goncalves et al., 2016). Cooking in an alkaline solution containing "kanwa" (naturally-occurring rock-salt) decreases thiamin, niacin and riboflavin levels compared to cooking without "kanwa" (Uzogara, Morton and Daniel, 1991). Fermentation results in a significant increase in the levels of thiamin and niacin (Akinyele and Akinlosotu, 1991).

Table 3.4. Proximate and fibre composition of cowpea whole grain

Percentage of dry matter

	Hussain and Basahy (1998)[a]	Maia et al. (2000)[a]		Rivas-Vega et al. (2006)[b]	Carvalho et al. (2012)		Devi, Kushwaha and Kumar (2015)[c]		Heuzé and Tran (2015)[a]		Yewande and Thomas (2015)		USDA-ARS (2016)
	mean	*mean*	*range*	*mean*	*mean*	*range*	*mean*	*range*	*mean*	*range*	*mean*	*range*	*mean*
Ash	3.6	3.6	3.2-4.1	3.9	3.7	3.0-4.1	4	3.8-3.9	4.1	3.1-5.8	3.7	3.7-3.7	3.39
Carbohydrate*	58.8	71	68-73	74.8	40.6	30-52	66	62-68			53.6	53.4-54.7	59.6
Crude fibre				2.6	24.2	18-32	4.57	4.3-5.0	5.6	2.5-10.5	4.4	4.3-4.5	10.7[d]
Crude protein	23	22.7	20-26	26.1	20.3	16-25	27.7	25-31	25.2	18.2-30.4	23.4	22.8-23.9	23.9
Crude fat	3.4	2.4	1.2-3.6	1.05	1.2	1.2-1.4	2.2	2-2.5	1.6	0.5-3.9	2	1.9-2.1	2.1
Water (% of fresh weight)	11.2	13	12-14	7.9			7.8	6.9-9.8	10.1	5.2-14.2	12.9	12.2-13.7	11.1

Notes: * Unless otherwise indicated, carbohydrate is measured by difference.
a. Carbohydrate values include fibre.
b. Anthrone method used to measure carbohydrates.
c. Carbohydrate measured as a nitrogen-free extract.
d. This value is for total dietary fibre and not crude fibre.

Table 3.5. Proximate and fibre composition of cowpea decorticated grain (DecGrain), leaves and aerial parts

Percentage of dry matter

	Rivas-Vega et al. (2006)		Devi, Kushwaha and Kumar (2015)[a]		Heuzé et al. (2015)[b]		Yewande and Thomas (2015)	
	DecGrain	**Sprouts[b]**	**Sprouts[c]**		**Leaves/aerial**		**DecGrain**	
	mean	*mean*	*mean*	*range*	*mean*	*range*	*mean*	*range*
Ash	3.75	4.23	4.2	3.9-4.5	11.3	8.1-14.4	2	2.0-2.0
Carbohydrate*	78.9	85.9	62.3	59.7-65.2			57.9	57.8-57.9
Crude fibre	0.8	2.12	6	5.1-6.5	24.1	11.5-35.9	1.4	1.4-1.4
Crude protein	25.6	29.5	30.6	28.1-33.6	18.1	13.5-24.3	21.3	20.8-21.8
Crude fat	1.29	1.4	2.2	2.0-2.5	2.8	1.3-4.1	1.6	1.6-1.6
Water (% of fresh weight)	7.85	6.36	9.2	8.5-10-6	79.1	88.9-73.6	15.9	15.3-16.4

Notes: * Unless otherwise indicated, carbohydrate is measured by difference.
a. Carbohydrate measured as a nitrogen-free extract.
b. Sprouts germinated for 3 days.
c. Sprouts germinated to be ¼ - ½ inches in length.

Table 3.6. Amino acid composition of cowpea whole grain

Percentage of total protein

Amino acid	Iqbal et al. (2006)	Adebooye and Singh (2007)		Khattab, Arntfield and Nyachoti (2009)		Vasconcelos et al. (2010)		Carvalho et al. (2012)[b]		Heuzé and Tran (2015)[b]		USDA-ARS (2016)[c]	Goncalves et al. (2016)
	mean	mean	range	mean	range	mean	range	mean	range	mean	range	mean	range
Alanine	4.2			4.6	4.6-4.5			4.8	4.5-5.0	4.2	3.4-5.1	4.6	4.2-4.5
Arginine	7.5			7.2	6.7-7.7	7.6	6.4-9.9	7.6	7.0-8.5	6.7	5.0-8.7	7	6.8-10.8
Aspartic acid	10.8			11.3	11-11.4			10.8	6.0-11.5	10.4	9.2-12.7	12.2	11-13
Cysteine	0.5			0.3	0.3-0.3					1.1	0.6-1.4	1.1	0.6-2.4
Glutamic acid	17.2			18.3	18-18.5			17.8	8.5-18.6	15.8	14.1-18.7	19.1	17-19
Glycine	3.8			4.3	4.1-4.5			4.1	3.2-4.3	3.9	3.1-4.8	4.2	4.1-4.4
Histidine	3.1	3.5	3.4-3.6	3.1	3.1-3.2	3.8	2.0-4.5	3.7	2.2-4.0	3.1	2.4-4.1	3.1	2.7-3.4
Isoleucine	4.5	4.8	4.7-4.9	3.8	3.8-3.8	4.4	3.8-5.4	3.8	3.0-4.7	4	2.8-5.2	4.1	3.9-4.5
Leucine	7.7	8.5	8.3-8.7	7.7	7.7-7.7	7.3	5.7-8.2	8.3	7.9-9.8	7.4	5.8-11.3	7.7	7.5-7.8
Lysine	7.5	7.2	7.1-7.2	5.8	5.7-5.9	6.1	3.9-8.1	8.0	7.6-8.3	6.5	5.2-7.1	6.8	3.5-7.9
Methionine	2.2	1.6	1.5-1.6	1.8	1.5-2.1			1.7	1.6-1.8	1.4	0.9-1.6	1.4	1.1-3.5
Phenylalanine	7.5	5.9	5.8-6.0	5.6	5.5-5.8			10.3	9.9-10.6	5.5	4.4-6.4	5.9	
Proline	4			5.7	5.6-5.9			8.1	7.6-8.9	4.6	3.8-5.7	4.5	3.1-6.2
Serine	3			5.5	5.4-5.6			5.2	4.5-5.8	4.9	3.8-5.6	5.1	4.0-5.2
Threonine	3.8	3.7		4.1	4.0-4.1	4.4	3.2-5.9	4.0	4.0-4.1	3.8	3.0-5.3	3.8	3.4-4.0
Tryptophan	0.7			1.1	1.0-1.1			1.3	1.1-1.5	1.1	0.9-1.3	1.2	1.1-1.3
Tyrosine	3			3.5	2.9-4.0					3	2.6-3.6	3.2	3.4-4.5
Valine	5	5.8	5.7-5.9	4.9	4.7-5.1	4.7	4.0-6.3	4.6	3.6-5.9	4.7	3.4-5.5	4.8	4.5-6.2

Notes: a. Total protein was chosen instead of dry weight because protein content is influenced by environmental factors and between seasons.
b. Cysteine values included in methionine data. Tyrosine values included in phenylalanine data.
c. Recalculated from g/100 g edible portions of grain.

Table 3.7. Amino acid composition of cowpea decorticated grain (DecGrain), leaves and aerial parts

Percentage of total protein[a]

Amino acid	Iqbal et al. (2006)	Adebooye and Singh (2007)		Heuzé et al. (2015)		Goncalves et al. (2016)
	DecGrain	**DecGrain**		**Leaves/aerial**		**Leaves**
	mean	mean	range	mean	range	range
Alanine	4.2			4.6		5.8-9.8
Arginine	7.5					16.1-17.3
Aspartic acid	10.8					17.0-26.7
Cysteine	0.5			0.9	0.9-0.9	1.0-2.9
Glutamic acid	17.2					24.3-45.3
Glycine	3.8			4.8		8.5-12.6
Histidine	3.1	3.2	3.2	1.8		6.6-8.6
Isoleucine	4.5	4.2	4.1-4.2	4.3		9.8-11.1
Leucine	7.7	8.2	7.9-8.4	7.4		17.9-19.6
Lysine	7.5	7	6.9-7.0	3.3	3-3.5	10.3-16.3
Methionine	2.2	1.4	1.3-1.5	1.4	1-1.8	2.9-4.5
Phenylalanine	7.5	5.7	5.6-5.7	4.6		12.6-14.4
Proline	4					10.4-15.9
Serine	3					11.4-11.6
Threonine	3.8	3.4	3.2-3.5	4	3.4-4.6	7.8-10.8
Tryptophan	0.7			1.3	1.3-1.4	2.4-4.1
Tyrosine	3			3.2		6.5-9.3
Valine	5	5.5		5.3		11.5-12.8

Note: a. Total protein was chosen instead of dry weight because protein content is influenced by environmental factors and between seasons.

Table 3.8. Levels of minerals in cowpea whole grain

Mineral	Akinyele and Akin-losotu (1991)	Boukar, Massawe and Muranaka (2011)		Belane and Dakora (2012)		Carvalho et al. (2012)		Heuzé and Tran (2015)[a]		USDA-ARS (2016)[a]
	mean	mean	range	mean	range	mean	range	mean	range	mean
Macro-minerals (mg/g dry matter)										
Calcium	0.446	0.826	0.31-1.395	0.6	0.37-1.13	0.37	0.29-0.51	1.1	0.3-2.7	0.95
Phosphorus		5.06	3.45-6.73	4.7	3.8-4.7			4.2	2.1-5.4	4.92
Potassium	12.36	14.89	11.40-18.45	13.3	11.4-16.4	11.07	9.57-12.51	15	12.8-21.5	15.44
Magnesium	0.905	1.92	1.52-2.50	1.7	1.3-2.4	1.46	1.30-1.69	2.2	1.6-2.8	3.74
Micro-minerals (mg/100 g dry matter)										
Copper				0.6	0.5-0.8	2.1	2.0-2.2	0.9	0.6-1.4	1.2
Iron	16.9	5.3	3.4-8.0	6.1	4.8-9.7	6.9	6.0-8.1	42.2	9.6-135.6	11.2
Manganese				3.3	2.1-4.3	2	1.7-2.9	2	1.4-3.2	1.7
Sodium						12.5	8.4-17.7	10	10-20	65
Zinc	4.5	3.8	2.2-5.8	4.3	3.3-6.5	3.3	2.7-4.4	3.8	2.4-4.6	6.9

Note: a. Recalculated from wet weight data where the water content was 11.05 g/100 g wet weight.

Table 3.9. Levels of minerals in cowpea decorticated grain (DecGrain) and leaves

Mineral	Akinyele and Akinlosotu (1991)	Iqbal et al. (2006)	Adebooye and Singh (2007)		Belane and Dakora (2012)		Heuzé et al. (2015)	
	DecGrain	**DecGrain**	**DecGrain**		**Leaves**		**Leaves/aerial parts**	
	mean	mean	mean	range	mean	range	mean	range
Macro-minerals (mg/g dry matter)								
Calcium	0.43	1.76	7.64	7.53-7.75	24.5	15.20-46.20	12.5	6.8-20.6
Phosphorus		3.03			4	2.30-6.10	2.4	1.1-5.2
Potassium	11.31	12.8	7.4	6.90-7.87	21.6	9.30-35.60	19.1	10.9-31.6
Magnesium	0.86	0.05	3.46	3.02-3.90	5.6	4.30-8.40	3.1	1.9-5.0
Micro-minerals (mg/100 g dry matter)								
Copper		9.7	0.95	0.9-1.0	1.3	0.9-2.2	3.0	
Iron	11.5	2.6	4.6	4.4-4.8	38	17-216	169	
Manganese		1.7	1.5	1.1-1.9	96	37-204		
Sodium		102						
Zinc	4.3	5.1	9	7.4-9.8	8.3	3.8-22.3	4.6	

Table 3.10. Vitamin levels in cowpea whole grain

mg/100 g dry matter

Vitamin	Elias, Bressani and Colindre (1964)		Uzogara, Morton and Daniel (1991)	Goncalves et al. (2016)	USDA-ARS (2016)[a]
	mean	range	mean	range	mean
Vitamin A				0.07	0.02
Vitamin B1 (thiamine)	0.74	0.41-0.99	0.77	0.2-1.7	0.76
Vitamin B2 (riboflavin)	0.42	0.29-0.76	0.25	0.1-0.3	0.19
Vitamin B3 (niacin)	2.81	2.51-3.23	3.45	0.7-4.0	3.14
Vitamin B5 (pantothenic acid)				1.7-2.2	
Vitamin B6 (pyridoxine)				0.2-0.4	0.41
Vitamin B7 (biotin)				0.02-0.03	
Vitamin B9 (folic acid)				0.1-0.4	
Vitamin B12 (cobalamin)				Trace	0
Vitamin C					1.69
Vitamin D (D2+D3)					0
Vitamin E				2-20	

Note: a. Recalculated from wet weight data where the water content was 11.05 g/100 g wet weight.

Anti-nutrients and other constituents

Anti-nutrients

Cowpeas contain some constituents that have anti-nutritional effects. These include oligosaccharides, phytic acid, polyphenols, protease inhibitors and lectins.

Oligosaccharides

For some humans, flatulence is a constraint to the consumption of cowpeas and other legumes. This response to legumes, which may vary according to gender, age, composition of colonic microflora and other factors, is attributed mainly to oligosaccharides that include stachyose, raffinose and verbascose. These oligosaccharides escape breakdown and absorption in the stomach and small intestine and are fermented by microorganisms present in the colon resulting in the production of flatus and other attendant discomfort (Onyenekwe, Njoku and Ameh, 2000; Phillips and Abbey, 1989). The concentration of oligosaccharides in cowpeas varies between varieties (Table 3.11).

Dehulling, soaking, germination and cooking can reduce oligosaccharide content (Aguilera et al., 2013; Akinyele and Akinlosotu, 1991; Akpapunam and Achinewhu, 1985; Egounlety and Aworh, 2003; Goncalves et al., 2016; Onyenekwe, Njoku and Ameh, 2000; Phillips, 2012; Singh, 2014; Somiari and Balogh, 1993; Uzogara and Ofuya, 1992).

Phytic acid

In legumes, the major portion of the phosphorus is present in the form of phytic acid (Reddy, Sathe and Salunkhe, 1982). Phytic acid can reduce the bioavailability of minerals and the digestibility of protein and starch by inhibiting proteases and amylases (Goncalves et al., 2016; Thompson and Yoon, 1984; Reddy, Sathe and Salunkhe, 1982). Phytic acid levels vary between varieties (Table 3.12) and may be altered with drying, storage, dehulling, soaking, germination, fermentation, cooking or roasting (Goncalves et al., 2016; Egounlety and Aworh, 2003; Adebooye and Singh, 2007). For example, phytic acid decreased 4 to 16 fold in sprouted grains (Devi, Kushwaha and Kumar, 2015).

Polyphenols

Polyphenols are included as anti-nutrients as they play a role in the reduction of protein and starch digestibility (Thompson and Yoon, 1984), and range in concentration among cowpea varieties (Table 3.12). Significant genetic variability was found for total flavonoid content and antioxidant activity in cowpea grains (Nassourou et al., 2016).

Polyphenols are mainly present in the seed coat. Cultivars with a coloured seed coat contain more polyphenols than white-seeded cultivars which have no detectable tannin, a polyphenol (Kachare, Chavan and Kadam, 1988). Cooking and dehulling reduce total phenolic content (Adebooye and Singh, 2007). Germinating cowpea seedlings have slightly higher polyphenol concentrations than raw cowpea grains (Aguilera et al., 2013).

Table 3.11. Oligosaccharide content in cowpea whole grain and decorticated grain (DecGrain)

mg/g dry weight

	Akpapunam and Markakis (1979)		Onigbinde and Akinyele (1983)				Phillips and Abbey (1989)		Akinyele and Akinlosotu (1991)		Somiari and Balogh (1993)		Muranaka et al. (2016)	
	Grain		**Grain**		**DecGrain**		**Grain**		**Grain**	**DecGrain**	**Grain**		**Grain**	
	mean	range	mean	range	mean	range	mean	range	mean	mean	mean	range	mean	range
Raffinose	12	11-12	26	13-42	17.8	5.8-33.9	3.8	2.9-4.7	20	8.5	25	22-28	3.4	1.7-4.5
Stachyose	34	29-41	33	12-50	24	8.9-37.5	20	17-22	36	30	42	33-48	31	24-43
Verbascose	9	6-10					5	3.8-6.0	40	9.5				

Table 3.12. Phytic acid and polyphenol composition in cowpea whole grain, decorticated grain (DecGrain) and sprouts

mg/g dry weight

	Preet and Punia (2000)		Madode et al. (2011)		Afiukwa et al. (2012)		Devi, Kushwaha and Kumar (2015)				Muranaka et al. (2016)	
	Grain		**Grain**		**DecGrain**		**Grain**		**Sprouts**		**Grains**	
	mean	range	mean	range	mean	range	mean	range	mean	range	mean	range
Phytic acid	9.1	8.2-9.5	3.3	0.8-5.0	3.1	2.6-3.9	3.4	3.1-3.8	0.46	0.2 0.7	28.3	22-37
Polyphenols	8.5	7.8-9.3	5.4	0.7-9.1							4.3	0.1-49

Protease inhibitors and lectins

Protease inhibitors and lectins are heat-labile and inactivated by cooking (Boukar et al., 2015) but are important to the plant as they have a role in protecting the plant from certain pests and diseases (Bell et al., 2001; Xu et al., 1996; Zhu et al., 1994; Machuka et al., 2000; Marconi, Ruggeri and Carnovale, 1997). Trypsin inhibitors are regarded as one of the most important anti-nutritional factors in cowpeas (Kochhar, Walker and Pike, 1988) and their levels vary considerably across cowpea varieties (Table 3.13). Germinating cowpea seedlings had reduced trypsin inhibitors but similar levels of chymotrypsin inhibitors compared to raw cowpea grains (Aguilera et al., 2013; Devi, Kushwaha and Kumar, 2015).

Lectins are found in most plants and are glycoproteins that selectively and reversibly bind carbohydrates, resulting in reduced nutrient absorption (Zhang et al., 2009). Lectin levels also vary widely among cowpea varieties (Table 3.13).

Table 3.13. Protease inhibitor activity (trypsin and chymotrypsin inhibitors) and lectin (measured by haemagglutination activity) in dry cowpea grain and decorticated cowpea grain (DecGrain)

	Units	Marconi, Ng and Carnovale (1993)[a,c]		Carvalho et al. (2012)[b,c]		Afiukwa et al. (2012)[a,d]	
		Grain		Grain		DecGrain	
		mean	range	mean	range	mean	range
Trypsin inhibitor	TIU/mg	19	9-47	2.8	2.2-4.2	21	15-28
Chymotrypsin inhibitor	CIU/mg	18	7-56	2.9	2.3-3.8		
Haemagglutination activity	HU	286	13-1173	220	40-640	64	5-83

TIU = trypsin inhibitor units; CIU = chymotrypsin inhibitor units; HU = haemagglutination units.

Notes:
a. Trypsin and chymotrypsin inhibitor expressed as units/mg flour.
b. Trypsin and chymotrypsin inhibitor expressed as units/mg protein.
c. Haemagglutination activity expressed as the reciprocal of the highest dilution (g/mL) resulting in positive agglutination.
d. Haemagglutination activity expressed as activity per g of flour (as per Liener and Hill, 1953).

Allergens

Allergic reactions to legumes, including peanuts and soybeans, are relatively common (Verma et al., 2013) but are rare for cowpeas. However, Rao et al. (2000) reported that serum from six individual patients that were allergic to cowpeas identified 41 kDa and 55 kDa proteins to be the major allergens of cowpea.

Suggested constituents to be analysed related to food use

Key products consumed by humans

The cowpea is a staple food and provides a major source of protein, and very likely other nutrients, to many people in Africa and elsewhere. Typically, the cowpea is consumed after having been soaked in water and cooked. Cowpeas are also consumed as roasted dried grain, flour, seedlings, leaves and green pods.

Suggested analysis for food use of new varieties

The cowpea can provide protein, carbohydrates, vitamins and dietary fibre. It also contains anti-nutrients such as lectins, oligosaccharides, phytic acid and trypsin inhibitor. These constituents are recommended for analysis of new cowpea varieties for food use (Table 3.14).

Table 3.14. Suggested nutritional and compositional parameters to be analysed in the cowpea for food use

Constituent	Grain
Proximates*	x
Amino acids	x
Fibre	x
Niacin	x
Riboflavin	x
Thiamine	x
Lectins	x
Raffinose	x
Stachyose	x
Phytic acid	x
Trypsin inhibitor	x

Note: * Proximates are Crude protein, Total lipid (fat), Ash, Carbohydrate (by difference) and Moisture.

Suggested constituents to be analysed related to feed use

Key products consumed by animals

The majority of cowpea grain is used for human consumption. Plant parts not used by humans are often used as fertiliser, grazed by livestock or harvested for fodder.

Suggested analysis for feed use of new varieties

The cowpea is an important animal feed that is able to provide good levels of protein, carbohydrates, vitamins and minerals for a range of animal species and these constituents are suggested for analyses for feed use (Table 3.15). A number of anti-nutrients are also relevant for feed use. An anti-nutrient effect is not an intrinsic property of a compound but also depends on the physiology of the ingesting animal. For example, trypsin inhibitors do not exert any anti-nutrient effects on ruminants as they are degraded in the rumen (Akande and Fabiyi, 2010).

Table 3.15. Suggested nutritional and compositional parameters to be analysed in the cowpea for feed use

Constituent	Grains	Leaves
Amino acids	x	
Neutral detergent fibre (NDF)	x	x
Acid detergent fibre (ADF)	x	x
Lectins	x	
Trypsin inhibitor	x	
Phytic acid	x	
Calcium	x	x
Proximates*	x	x

Note: * Proximates are Crude protein, Total lipid (fat), Ash, Carbohydrate (by difference) and Moisture.

Notes

[1] The terms "seed" and "grain" are often used in literature with equivalent meaning. This is also the case in this document where the use of these terms were harmonised as far as possible along the following principles: the term "seed" refers to a grain intended for sowing, or is used in specific botanical descriptions of the grain as being a distinct part of the plant (e.g. "seed coat"). The term "grain" is used in all other cases, more directly referring to the harvested product intended for food and feed. In addition, for legume crops, grain is sometimes referred to as "grain legume" or "legume".

[2] For additional discussion of appropriate comparators, see the Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant DNA Plants CAC/GL 45/2003 of the Codex Alimentarius Commission (paragraphs 44 and 45).

[3] These include breeding programmes at the International Institute of Tropical Agriculture (IITA) in Nigeria, the USAID Bean/Cowpea Collaborative Research Support Program (CRSP), the University of California (UCR), the Texas A&M University and the Brazilian Agricultural Research Corporation (Embrapa).

[4] E.g. biofortication for higher levels of iron and zinc (Rocha, 2015).

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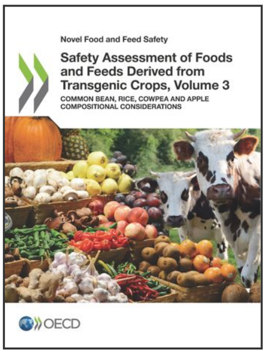

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