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Iron and zinc in commercial and biofortified whole cowpea flours and in akaras

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Abstract

Cowpea bean is a legume highly consumed in Brazil, mainly in the North and Northeast regions, and is considered an excellent source of protein, iron, and zinc. The deficiency of these micronutrients mainly affects children and women from developing countries. Biofortification of cowpea grains has been applied to produce foods with high nutritional content, and its flour is used in different types of preparations, mainly to obtain akara. The objective of the study was to evaluate the iron and zinc contents of three biofortified grains and one commercial sample, the flours, and the akaras. The cultivar biofortified cowpea cultivars (BRS Xiquexique, BRS Tumucumaque, and BRS Aracê) cultivated at Embrapa, Meio, Norte, Teresina, Piauí, Brazil were used for the experiments. A commercial sample was used as a control. Iron and zinc analyses were carried out by Atomic Emission Spectrometry, with an inductively coupled plasma source (ICP). All experiments were performed in three replications for each sample. The results were evaluated using analysis of variance (ANOVA), in a completely randomized design, to assess the presence of a significant effect ($p \leq 0.05$). The Tukey test was used to determine the differences among the averages. Although there were significant differences among the cultivars of iron and zinc, the ratio between iron and zinc was 2.08. BRS Xiquexique stood out among them, as did the akara formulation. All the results revealed that biofortified cowpea cultivars would be a viable alternative for enriching foods and obtaining akara with high nutritional value and other products.

Keywords: biofortification; iron and zinc; commercial and biofortified cowpea flours; akara.

Practical Application: Cowpea and conventional and biofortified grains are a nutritive stapple food.; Iron and zinc contents are high to minimize deficiencies.; Whole cowpea flours is used to formulate many thypical meals and dishesplates in Brazil. The Akara is widelyvery consumed in the state of Bahia state and.; All the biofortified cowpea Akara have been shownshowed to be a viable alternative for enriching foods and obtaining Akara with high nutritional value.

1 INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is a crop of African origin, which was introduced in Brazil in the second half of the 16th century by Portuguese colonizers in the State of Bahia. Classified as a Dicotyledonous plant, of the order Fabales, family Fabaceae, subfamily Faboideae, tribe Phaseoleae, subtribe Phaseolineae, genus *Vigna*, subgenus *Vigna*, section Catyang, species *Vigna unguiculata* (L.) Walp and subspecies *unguiculata* (Freire Filho, 1988). Cowpea bean is a legume widely consumed in sub-Saharan Africa (Phillips et al., 2021) and in Brazil, cultivated in the North and Northeast regions considered an excellent source of protein, iron, and zinc. The deficiency of these micronutrients mainly affects children and women in underdeveloped countries (Affrifah et al., 2022). Studies have been carried out with new cowpea cultivars to evaluate the effectiveness of biofortification and their nutritional quality (Pereira, 2013; Pereira, 2014; Yadav et al., 2023).

According to Dias-Barbosa et al. (2021) and Fernandes et al. (2021) biofortification of cowpeas can improve iron and zinc contents and has been applied to produce meals and products with high nutritional content, and its flour is used in different types of preparations, mainly to obtain akara, "baião de dois," "pão de queijo" (cheese bread), cookies, soups, and bakery products, among other products. The use of whole cowpea flour is viable in foods other than akara.

Fernandes et al. (2021) reported new findings about biofortified and non-biofortified cowpea cultivars as well as some common beans observing that biofortified cowpea cultivars showed high levels of Fe and Zn (BRS Aracê), greater than 60 and 40 mg kg^{-1} dry weight, respectively. The cooked biofortified BRS Aracê cowpea showed a high Zn bioavailability above 60%. Consumption of 50 g of BRS Aracê would contribute 27% and 48% of the Fe and Zn DRI for 1- to 3-year-old children. The new cowpea cultivars biofortified are a potential vehicle for improving the Fe and Zn *status* in groups in which micronutrient deficiency is prevalent. 50 g of biofortified Aracê cowpeas contribute 27 and 48% of the Fe and Zn DRI for 1- to 3-year-old children.

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The BRS-Milênio cultivar was developed to promote its resistance against pests and productivity, obtained through genetic improvement in order to evaluate its nutritional potential. The iron and zinc values were, respectively, 6.8 and 4.1 mg 100 g^{-1}.

According to Oliveira et al. (2023), cowpea is a socioeconomically important legume in the Northeast region of Brazil, and a low-cost protein source, reporting iron and zinc contents of the cultivars BRS Aracê, BRS Inhuma, and BRS Xiquexique, respectively: 6.58, 5.67, and 6.30 mg 100 g,$^{-1}$ and 3.92, 3.60, and 3.92, mg 100 g^{-1}.

Leal et al. (2013) found that biofortified cowpea flours have favorable physical and chemical properties and nutritional value for the development of food products, due to their good stability, high protein, and mineral content as well as high water solubility index. This is a good indication for the production of foods such as soups and porridge.

Additionally, Cavalcante et al. (2016) concluded that cowpea flour is a valid option for enriching gluten-free baked foods, providing an alternative for introducing the product into the market (Jackson et al., 2022).

According to Rios et al. (2018), all whole cowpea flours demonstrated an excellent nutritional profile, being potentially suitable for baking. Rogério et al. (2014) evaluated the color preference of akaras made with two cultivars of cowpea *olho de pombo* and *macassar* finding *olho de pombo* the most preferred.

The original formulation of akara comes from West Africa and arrived in Brazil through slaves from that region. In Africa, the dish based on fried cowpea paste, known as akara, is one of the most consumed by the local population to this day (Brasil, 2004).

To prepare traditional akara, cowpea grains are immersed in water for at least 14 hours, then drained to remove residual water and rubbed to remove the skins. The peeled grains are placed in 500 mL beakers and added with salt, crushed onion and mixed with flour, and fried in two glasses of palm oil (400 mL) that are normally used (Globo, 2018).

500 g of raw black-eyed peas, 1 medium onion cut into pieces.

Many other products and formulations can be elaborated from the cowpea flours (whole or decorticated), and cookies are one of them. Fiorentin et al. (2019) evaluated the acceptability of cookies formulated with the BRS Xiquexique flour in formulations of 15% and 30% and a control sample. The acceptability was similar to the control. The iron and zinc contents were higher in formulations F2 (15%) and F3 (30%) iron as expected, concluding that cookies with the addition of biofortified cowpea flour are sources of iron and zinc and are capable of meeting the recommended needs, being a viable option for the food products industry. Landin et al. (2019) used the biofortified cultivar (BRS Xiquexique) flour for cookies and reported excellent macro and micronutrient content (mainly iron and zinc), being a product with great nutritional and functional potential as a viable option for use in interventions related to nutritional deficiencies such as iron deficiency anemia.

The *Baião de Dois*, a Brazilian dish/meal very popular in the Northeast elaborated (cooked with biofortified cowpea and rice) BRS Aracê, BRS Tumucumaque, and BRS Xiquexique. Costa et al. (2015) observed that the formulation was the most rejected because the long cooking time resulted in a product without uniformity, while the BRS Xiquexique was better accepted and recommended for formulating the *Baião de Dois*.

Cavalcante et al. (2016) developed cheese bread enriched with biofortified whole cowpea (BRS Xiquexique) flour, evaluating its chemical composition and acceptance. Formulations F1 and F2 were prepared containing 5.6 and 8%, respectively, of cowpea flour replacing starch. The results showed an increase in the levels of proteins and carbohydrates, as well as copper, iron, phosphorus, magnesium, manganese, and zinc, and a reduction in the total caloric value in relation to the standard formulation. The use of cowpeas may be a viable option for the enrichment of baked foods that do not contain gluten, such as cheese bread.

An issue that must be taken into consideration, and which has already been consolidated in previous studies, is that the nutritional akara composition can vary depending on the quality of the grains, their genotypes, harvesting conditions, and the processes used to produce the paste (Almeida et al., 2020).

1.1. Relevance of the work

The relevance of the present study was based on the retention of iron and zinc in whole or biofortified cowpea beans, as well as in flours and akaras, allowing their use in many types of foods and meals with increased supply of these micronutrients.

2. MATERIAL AND METHODS

2.1. Samples, process, and analyses

Biofortified cowpea grains from BRS Tumucumaque, BRS Aracê, and the BRS Xiquexique cultivars were provided by Embrapa Meio, Norte located in Teresina, Piauí, Brazil (cultivated in 2021), and a commercial cowpea was used as the control. After receipt, the samples of each cultivar and control were placed in high-density polyethylene plastic bags and kept under refrigeration at 1°C until grinding.

The whole grains of biofortified and commercial cowpea (control) were sent to the Cereals Laboratory of EMBRAPA, Food Technology, Rio de Janeiro, and ground to obtain whole grains flour and determine particle size. The grains were ground in an LM 3100 hammer mill (Perten Instruments AB, Huddinge, Sweden) equipped with a 0.8 mm sieve A, without prior maceration in water, in order to avoid nutritional losses in the flour.

To obtain the akaras, 60 g (38%) of whole cowpea flour from each biofortified cultivar and control was added to 85 mL (48%) of drinking water, 20 g (13%) of processed onion, and 1 g (0.6%) of salt.

Next, the akaras were fried in palm oil at temperatures and times varying from 150 to 180°C for approximately 3–4 min.

2.2. Iron and zinc of flours and akaras

The determination of iron and zinc of the flours and the akaras was carried out by atomic emission spectrometry, with an inductively coupled plasma source (ICP). All experiments were performed in three replications for each sample.

2.3. Statistical analysis

The results were evaluated using analysis of variance (ANOVA) in a completely randomized design to assess the presence of a significant effect ($p \leq 0.05$). The Tukey test was used to determine the differences among the averages.

3. RESULTS AND DISCUSSION

The whole BRS Xiquexique cowpea flour presented the best iron content (63.38 mg kg^{-1}), followed by BRS Aracê (54.79 mg kg^{-1}). The best zinc content was found in BRS Tumucumaque (41.59 mg kg^{-1}) and BRS Aracê (37.36 mg kg^{-1}). Although there were significant differences ($p < 0.05$) among the iron and zinc, BRS Xiquexique stood out among them presenting the best relation ratio between iron and zinc (2.08) (Table 1).

Osunbitan et al. (2016) found that the cowpea flours from IT90K-277-2 and IT97K-568-18 cultivars had iron and zinc contents varying from 13.14 to 20.58 and 23.02 to 25.20 mg kg^{-1}, respectively.

Coelho et al. (2021) evaluated the raw and cooked biofortified and nonbiofortified cultivars of cowpea regarding iron and zinc contents and their bioaccessibility and bioavailability verifying that the contents of iron and zinc were greater than 60 and 40 mg kg^{-1} (dry) weight. Cooking improved the availability of micronutrients in bean seeds. The cooked Aracê cultivar showed the best zinc availability greater than 60%. Consumption of 50 g of Aracê would contribute 27 and 48% of the Fe and Zn DRI for 1- to 3-year-old children.

In our study, the iron content varied from 52.11 (commercial) to 66.75 (BRS Xiquexique) and the zinc content from 29.50 (commercial) to 43.17 (BRS Aracê) on a dry basis presenting significative differences ($p < 0.05$) in akaras (Table 2). Compared with the values found by Feitosa et al. (2015), the iron and zinc contents found in this study were higher than the iron (39.51) and zinc (26.83 mg kg^{-1}) contents, respectively, in cowpea akaras (Table 2).

Frota et al. (2011) used biofortified cowpea flour from the BRS Xiquexique cultivar, replacing wheat flour, in biscuit and "rocambole" formulations, finding that the addition of 30% of biofortified cowpea flour in the biscuit increased iron content from 6.6 to 15.6 mg kg^{-1} and zinc from 4.2 to 12.8 mg kg^{-1}.

Corrêa (2018) obtained iron levels of 57.8 (BRS Aracê), 63.5 (BRS Tumucumaque), and 66.9 (BRS Xiquexique) in whole cowpea flours, in mg kg-^{1}, which are similar to our results for the same cultivars of biofortified flours, except BRS Tumucumaque (57.79 mg kg-^{1}).

Cavalcante et al. (2016) reported that enrichment with 5.6% biofortified cowpea flour from the BRS Xiquexique cultivar, in the cheese bread formulation, increased iron levels from 34 to 72 mg kg-^{1} and zinc levels from 18.7 to 23.9 mg kg^{-1}.

Akaras from BRS Xiquexique showed the highest iron content and the lowest zinc content but presented a good Fe/Zn ratio. In general, according to age group and sex, a 50 g portion of akara from BRS Xiquexique meets 10–23% of the daily iron requirements and 8–18% of zinc.

Chickwendu (2007) reported lower iron (24.4) and higher zinc (46.6) mg kg^{-1} contents in commercial cowpea akaras than those in the present study, whereas Feitosa et al. (2015) found lower iron and zinc levels of 39.51 mg kg^{-1} in cowpea akaras than those in the present study. It is observed that there is a great variation in iron and zinc levels in cowpea cultivars, but all biofortified cultivars proved to be suitable for akara preparations.

Fiorentin et al. (2019) evaluated the iron and zinc contents in cookies made with cowpea flour from the BRS Xiquexique cultivar, revealing an increase in iron and zinc contents from 9.0 to 23 mg kg^{-1} and from 32.0 to 131.0 mg kg^{-1}, respectively. On the other hand, Otitoju et al. (2015) compared the proximate composition of some minerals in the grains and in pottage from four varieties of cowpeas (*Vigna unguiculata*): Potiskum (black-eyed pea), Ife-brown (brown bean), Orarudi, and Aloka. They found 26.90% of the protein in Ife-brown cowpea grains and 15.70% in pottage as well as minerals (calcium, zinc, potassium, zinc, phosphorus, and iron). In this study, 50 g of akara contained 1.87 g of iron and 0.89 mg of zinc (Table 3).

Table 1. Iron and zinc (mg kg^{-1}) in whole commercial and biofortified flours (wet basis).

Flours	Iron	Zinc
Commercial	56.70 ± 1.08	32.34 ± 0.18
BRS Aracê	54.79 ± 0.95	37.36 ± 0.81
BRS Tumucumaque	59.94 ± 0.80	41.59 ± 4.55
BRS Xiquexique	63.38 ± 0.01	36.67 ± 0.13

Table 2. Iron and zinc contents in akaras.

Samples	Iron*	Zinc*
Commercial	52.11	29.5
BRS Xiquexique	66.75	31.94
BRS Aracê	54.77	43.17
BRS Tumucumaque	53.85	36.18

* mg kg^{-1}.

Table 3. Iron and e zinc (mg kg^{-1}) in akara obtained from commercial and biofortified sources and a portion of 50 g (wet basis).

Akaras	Iron	Portion (50 g)	Zinc	Portion (50 g)
Comercial cowpea	30.10 ± 0.02	1.50	17.02 ± 0.06	0.86
BRS Aracê	27.72 ± 0.30	1.38	21.85 ± 0.48	1.09
BRS Tumucumaque	25.87 ± 0.09	1.29	17.39 ± 0.04	0.87
BRS Xiquexique	37.35 ± 3.69	1.87	17.87 ± 0.60	0.89

According to age and sex, daily iron requirements in a portion of akara with whole cowpea flour are met by 8–15% (commercial sample), 8–17% (BRS Aracê), 7–16% (BRS Tumucumaque), and 10–23% (BRS Xiquexique).

4. CONCLUSION

Among the whole grain flours from the biofortified cowpea samples, there were no significant differences in iron and zinc contents. The akaras from BRS Xiquexique showed the highest iron content and the lowest zinc content but presented a good Fe/Zn ratio. In general, according to age group and sex, a 50 g portion of akara from BRS Xiquexique meets 10–23% of the daily iron requirements and 8–18% of zinc. Although the results obtained revealed BRS Xiquexique as the best, all biofortified cowpea cultivars can be viable alternatives for food biofortification and obtaining akaras and other products with high nutritional value.

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