Chapter 13

Foods Produced with Cowpea Flour as a Strategy to Control Iron Deficiency Anemia in Children

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Abstract

Cowpeas (*Vigna unguiculata* L. *Walp*) are widely distributed throughout the world, being a relatively cheap source of protein and energy, but underutilized in most countries. The World Health Organization (WHO) estimated that about 1.62 billion people are affected by anemia and that preschool children are the most affected, with a prevalence of 47.4%. Several countries have stepped up efforts to reduce iron deficiency anemia by supplementing iron, as well as universal fortification of foods with iron and other micronutrients and vitamins. Parallel to these programs, several intervention studies were carried out with the same objective, using various forms of food fortification/enrichment aimed at the control of anemia. Fortification/food enrichment has contributed to the reduction of the prevalence of anemia. The biofortification of foods, such as cowpea, produced in countries of Africa and Latin America, including Brazil, where the prevalence of anemia is high, deserves attention because can be used in the usual form of ingestion and also in the form of flour in the preparation of products for children, with greater acceptance by them, constituting a new and promising strategy to reduce the levels of iron deficiency anemia.

Keywords: cowpea, iron deficiency anemia, cowpea flour, children, enrichment, food fortified

1. Introduction

Among the various legumes, cowpea (*Vigna unguiculata* (L.) *Walp*) is present in tropical and subtropical regions, being widely distributed throughout the world. It is considered a relatively inexpensive source of protein and energy, but is still underutilized in most countries [1].

The World Health Organization (WHO) estimates a high prevalence of anemia in worldwide, with children being the most affected, especially at preschool age, leading to several injuries ranging from the reduction of physical capacity to the increase in propensity to infections and mortality [2].

In an attempt to reduce this problem, several countries have intensified actions directed to reduce this lack by iron supplementation as well as through the universal food fortification with iron and other micronutrients and vitamins [3, 4]. Cowpea tree genetic improvement programs, such as HarvestPlus, aim to obtain cultivars with high productivity, resistance to diseases, and biofortification with micronutrients, also improving the nutritional quality of the beans [5]. Concomitant to this process, studies have been carried out and enriched/fortified products have been developed in an attempt to help in the fight against iron deficiency anemia. In this sense, cowpea flour is a raw material with great potential to be used in the development of products aimed at children as a strategy to reduce and/or control iron deficiency anemia.

2. Cowpea

The cowpea (*V. unguiculata* L. *Walp*) is a legume found in several countries, from Africa to other developing and developed countries, such as the United States of America. For a large part of the population in several countries is the main source of protein, calories, dietary fiber, minerals, and vitamins [1, 6, 7]. It also has bioactive compounds, highlighting the phenolic compounds [8], which makes it potentially important for the human diet from the nutritional point of view. It is mainly consumed in the form of dry beans, and may also be eaten as a vegetable, in the form of fresh beans and pods, or in the form of flours obtained from dry beans, weighing 16.5 g (weight of 100 grains). The plant has a semipruned size, with flourishing of 40–45 days after sowing and cycle of 65–75 days after seeding [9–11]. Despite being a relatively inexpensive source of protein and energy, it is underutilized in many countries, especially the developed ones, while it has been incorporated as an important staple food of poor communities in developing countries [9].

In Brazil, it is one of the most important crops in the North and Northeast regions and in great expansion in the Midwest region of the country, which is adapted to the heat conditions and water deficiency present in these regions due to its rusticity and precocity [10, 12, 13]. Specifically in the Northeast, according to a survey by the Brazilian Institute of Geography and Statistics—IBGE, the production and the productivity yield around 258,187 t and 250 kg/ha, respectively, and the largest producing states of this region are the states of Bahia (106,653 t), Ceará (52,721 t), Maranhão (34,837 t), and Piauí (26,520 t) [14]. In this sense, the cultivation of cowpea in much of the country is held by family-based farmers; however, it has been incorporated into a production system of small, medium, and large companies, using modern technologies [15]. The growing interest in its cultivation has led to the production of several cultivars with good nutritional, culinary, and agronomic characteristic such as the Brazilian (BRS) cultivars BRS-Xiquexique, BRS-Aracë, BRS-Tumucumaque, BRS17-Gurguéia, BRS-Maratauã, among others [15, 16].

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Figure 1. Cowpea cultivars: (A) BRS-Aracê, (B) BRS-Xiquexique, and (C) BRS-Tumucumaque.

The HarvestPlus program is developing genetic improvement research of various foods around the world in an attempt to counter the most varied micronutrient deficiencies. Among the researches developed are of bean (*Phaseolus vulgaris*) and the cowpea (*Vigna unguiculata*), because these are the most common legumes in Latin America and Africa (East and southern regions), regions of high prevalence of iron deficiency anemia [5]. The Food and Agricultural Organization (FAO) presents estimates of cowpea production in 35 countries. In Brazil, the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) also develops biofortified agricultural products, one of which involves the cowpea (*V. unguiculata* (L). *Walp*), a species rich in iron (61.3 mg/kg), zinc (44.7 mg/kg), and protein (24 g/100 g), with several cultivars, among them, BRS-Aracê, BRS-Xiquexique, and BRS-Tumucumaque (**Figure 1**) [17].

In order to increase the efforts on complementary interventions to numerous nutritional deficiencies, biofortification has emerged as an option, in order to reduce the problems of deficiencies of several micronutrients, including iron, and is characterized by the increase of nutrient content in foods, through conventional breeding or genetic engineering [18, 19].

The biofortification of cowpea combined with the positive results obtained in intervention studies boosted research using cowpea flour in the development and improvement of commonly consumed products, sensorially accepted with nutritional characteristics superior to the standard formulation, such as cheese breads [20], blends containing cowpea flour for the production of fortified maize snack [21].

3. Nutritional and iron deficiency anemia

Nutritional anemia is defined as a pathological process in which the hemoglobin concentration in erythrocytes is abnormally low, with respect to the variation of age and sex, which is due to the lack of one or more essential nutrients such as iron, folic acid, and/or vitamins A, whatever the cause, with iron deficiency being the most common [22, 23]. Although different nutrients and cofactors are involved in the maintenance of normal hemoglobin synthesis, iron deficiency anemia has been the most widespread and frequent nutritional deficiency in the world, both in industrialized and developing countries, the prevalence being four times higher in the latter [23, 24].

The iron deficiency anemia, in turn, is characterized by the reduction or absence of iron reserves, low iron concentration in the serum, low transferrin saturation, low hemoglobin concentration, and hematocrit reduction. Initially, the forms of iron, ferritin, and hemosiderin, reserve decreased, with hematocrit and hemoglobin levels remaining normal. Furthermore, the serum iron level decreases and, concomitantly, the iron-binding capacity in transferrin increases, resulting in a decrease of the percentage of iron saturation in transferrin. Consequently, there is a slight decrease in red cells circulation. This stage can be called iron deficiency without anemia. The iron deficiency anemia represents the most advanced stage of hyposiderosis, characterized by the reduction of hemoglobin and hematocrit, which is reflected in changes in erythrocyte cytomorphology, presenting microcytosis and hypochromy and causing disturbance in the mechanism of oxygen transport, leading to inadequate supply of iron to the tissues and possible functional damage to the organism [24–26].

The World Health Organization (WHO), in a global analysis of anemia, estimated that about 1.62 billion people are affected by this condition across the world and that the preschool age children are most affected, with prevalence of 47.4% [2].

Some of the most varied injuries triggered by the installation of anemia in the infant population are the deficit of cognitive development, the reduction of physical capacity, the commitment of the work activity, the physical and psychomotor development retardation, depression of the immune system with a greater propensity to infections, and increased mortality [27]. These negative implications lead to severe damage in school performance, which means that this deficiency is considered a major public health problem in both developing and developed countries. Its consequences affect not only the population health but also the social and economic development of the world [2, 28, 29].

A serious and frequent problem in childhood anemia is the fact that many children are born to mothers who have iron deficiency anemia and therefore start in life with iron deficiency. This congenital iron deficiency can be further aggravated by nutritional insufficiency both qualitatively and quantitatively, further exacerbating the problem [30].

The highest susceptibility of anemia in children occurs at the preschool age, especially in children 24 months of age, strengthening the hypothesis that the disease is significantly more prevalent in younger children. This greater vulnerability can be attributed to the accelerated growth accompanied by a consequent increase in iron requirements in the first year of life. Low iron reserve at birth can also be an important factor in the onset of anemia, since the intrauterine mineral storage and exclusive maternal breastfeeding ensure that the needs of the infant are met only until the first 6 years of life [31].

Table 1 shows the studies performed in the period from 2014 to 2016 by different authors in the international scope that evaluated the prevalence of anemia in children. The results show that the prevalence of anemia is moderate to severe in several countries, including in Europe. This study was carried out in 19 European countries, highlighting the importance of interventions for the control, as it is a serious public health problem.

In Brazil, there is no national survey of prevalence of anemia; there are only studies in different regions of the country, showing a high notoriety, being considered an important public health problem, since it is not restricted to poor malnourished populations [39]. **Table 2** shows the prevalence of anemia in children from 2010 to 2016 in Brazil, according to different authors.

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Location	Sample number/age	Anemia (%)	Year	References
Ghana	2168/<5 years	78.4	2014	[32]
China	1290/6–23 months	49.5	2015	[33]
Peru	1372/<5 years		2015	[34]
	Indigenous	51.3		
	No indigenous	40.9		
Armenia	729/0–59 months	32.4	2015	[35]
Europe	7297/6–12 months	2–25	2015	[36]
	12–36 months	3–48		
Brazil	1210/2–6 years	26.3	2016	[37]
United States	1437/1–5 years	1.1	2016	[38]

Table 1. Prevalence of anemia in children in studies published between 2014 and 2016.

Region	Anemia (%)	Year	References
North	57.3	2011	[40]
North	30.6	2011	[41]
North	13.6	2012	[42]
North	51.8	2012	[43]
Northeast	92.4	2010	[44]
Northeast	32.8	2011	[45]
Northeast	36.5	2012	[46]
Northeast	35.0	2013	[47]
Northeast	36.0	2014	[48]
Northeast	26.3	2016	[37]
South	63.7 (12–16 months) 38.1 (3–4 years)	2010	[49]
South	29.7	2011	[50]
South	58.5	2011	[51]
Southeast	26.0	2011	[52]
Southeast	30.8	2012	[53]

Table 2. Prevalence of anemia in children by region of Brazil, studies published between 2010 and 2016.

4. Strategies for control of anemia

According to Stevens et al. [54], world awareness about anemia and its consequences for the health and development of women and children has increased in recent decades. In 2012, the 65th World Health Assembly adopted a plan of action and strategies for mothers and children with the goal of halving the prevalence of anemia in reproductive age until 2025, from 2011 levels, thus increasing attention to nutritional intervention initiatives [54].

Among the measures for the prevention and control of iron deficiency anemia, several countries have intensified actions directed to reduce this lack by iron supplementation as well as through the universal food fortification with iron and other micronutrients and vitamins [3, 4]. The most frequently used target vehicles for fortification are cereals [4]. In this sense, as other countries, Brazil instituted the universal mandatory fortification of wheat and maize flour with iron and folic acid in the last decade [55]. In parallel to these programs, several intervention studies have also been carried out in order to contribute to the control of this deficiency, through the development of interventional researches that use various forms of food fortification/enrichment aiming the anemia control.

The iron supplementation, according to WHO guidelines for direct daily iron supplementation, it should be considered a first-line intervention in high-risk or high-prevalence groups. In endemic regions, the empirical administration of anthelmintic medications may also be justified [2]. However, studies highlight the low adherence to supplementation with iron salts. Even when the supplements are available, and mothers are instructed to supplement their children, they often do not administer the correct dosage and long enough to get benefits in hemoglobin levels due to side effects such as diarrhea, cramps, among others [56, 57].

As a successful example of this type of intervention, we have the intervention performed by Moreira-Araújo et al. [58], who performed a nutritional intervention with a snack developed with chickpea, bovine lung, and corn, rich in iron for 60 days, three times a week, to control anemia in preschool children, decreasing the prevalence of anemia from 61.5 to 11.5% [58]. Other studies used iron-fortified cowpea in the interventions. Adom et al. [59] investigated the effect of iron-fortified maize-cowpea blend (ferrous fumarate added) in controlling iron deficiency anemia in Ghana's high-risk population. Fifty-six children aged 6–18 months were randomly assigned (i) iron-fortified food or (ii) noniron-fortified food, fed daily for 6 months. Significant differences were observed in hemoglobin concentration (1.08 ± 1.43 compared with 0.40 ± 1.72 g/dL, $p = 0.0009$), and the risk of developing anemia was about three times less likely among this group compared to the nonfortified group [59]. Another study conducted in Ghana with children aged 5–12 years with cowpea meal fortified with iron (NaFeEDTA) and nonfortified cowpea showed a reduction of 30 and 47% in the prevalence of iron deficiency and iron deficiency anemia, respectively, with the use cowpea meal fortified with iron (NaFeEDTA) indicating that when used for targeted school-based interventions, fortification of cowpea flour is effective in improving iron status and consequently reducing the prevalence of iron deficiency anemia [60].

On the other hand, Paganini et al. [61] warn of the risks of fortification of complementary foods at home by adding micronutrient powders, widely used in African countries. It also shows that, in controlled studies, these micronutrient powders containing iron significantly increase the risk of diarrhea in infants, with an increase in the number of hospitalization. These foods decrease the number of beneficial intestinal bacteria, increasing the ratio of enterobacteria to bifidobacteria, contributing to an increase in the number of opportunistic pathogens and inducing intestinal inflammation in school-age children [61].

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5. Product development with cowpea flour with potential to be used in interventions in children

The development of foods enriched/fortified has great importance not only for the food industry but also to raise the quality of food and nutrition of the population, since it is possible to create new products or improve existing ones with balanced compositions in relation to some nutrients, thus improving the nutritional value of various foods available in the market. Many of these products have been developed using unconventional raw materials selected to produce naturally enriched foods which are a means of substantially improve their nutritional quality [62]. Often these raw materials are not included in consumers' habits and can contribute to improve the intake of important nutrients that are not usually found in conventional foods [58, 63, 64]. Flour production has been outstanding for this purpose, as they are rich in starch and mineral salts and present great variability for the food industry, especially in bakery products, dietetic products, and baby foods [65]. In this sense, studies have been carried out using cowpea bean flour (**Figure 2**).

In 2010, Frota et al. [66] have developed a work whose objective was to enrich bakery products, such as cookie and *rocambole roulade* with cowpea flour, to evaluate their acceptance and chemical composition, including the mineral content (iron, zinc, magnesium, potassium, and phosphorus) and vitamins (thiamine and pyridoxine). For this, three cookie formulations containing 10, 20, and 30% of cowpea flour and two *rocambole* formulations containing 10 and 20% of the flour were developed. It was observed an increase in the protein content of the cookie with 30% and of the *rocambole* with 20% of cowpea flour and the amount of

Figure 2. Cowpea flour.

ashes of the cookies with 20 and 30% and rocambole with 20% of cowpea flour, when compared to the standard formulations. The content of the analyzed minerals and pyridoxine has increased as the cowpea flour was added, while the thiamine concentration increased only in the *rocambole* with 20% of the flour. The cookie with 10% of cowpea flour was the most sensorially accepted (84.4%) by means of the nine-point Hedonic scale sensory test, ranging from 1 "extremely disliked" to 9 "extremely liked," among the cookies formulated with the flour, in addition, the rocambole with 10 and 20% of the flour had good acceptance (86.7 and 77.8%, respectively). Thus, all formulations containing cowpea flour had scores higher than 6, showing that the products were sensorially accepted. Thereby, the study showed that the addition of cowpea flour improved the nutritive value of cereal-based formulations and that this practice is feasible [66].

Cavalcante et al. [20] developed a cheese bread enriched with whole grain biofortified cowpea flour and evaluated their acceptance and chemical composition (**Figure 3A**). For this, two formulations of cheese bread, F1 and F2, containing 5.6 and 8% of cowpea flour in substitution of flour, respectively. To check the acceptance, three sensorial tests (Hedonic scale, purchase intention, and matched comparison) were used, and F1 was sensorially viable, according to the assessors, being chemically analyzed. The addition of cowpea increased the levels of copper, iron, phosphorus, magnesium, manganese, and zinc, as well as the levels related to proteins and carbohydrates. On the other hand, the moisture contents, lipids, and total caloric content decreased when compared to the standard formulation. Therefore, it was concluded that cowpea, a raw material in evidence in the national market, presents itself as an option for the enrichment of gluten-free bakery foods, such as cheese bread, including improving the technological quality of this product in relation to the growth and expansion of the mass, providing a better texture, due to its chemical composition [20]. Shakpo and Osundahunsi

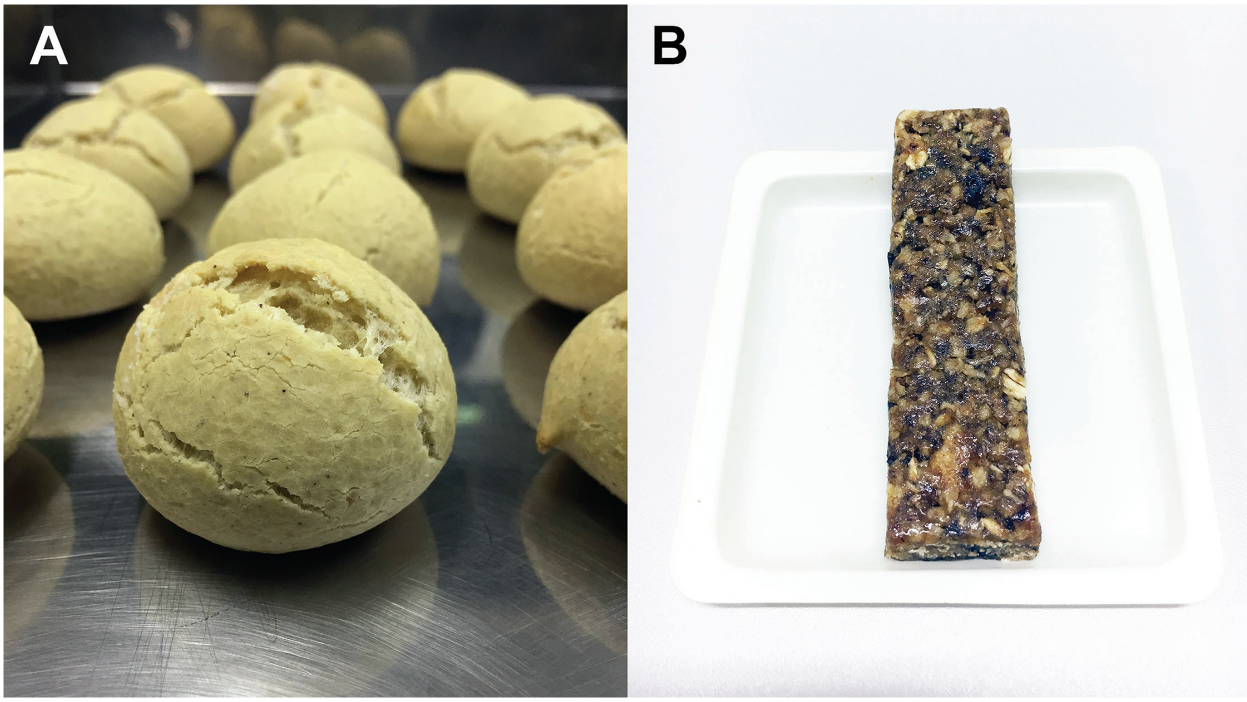

Figure 3. (A) Cheese bread and (B) cereal bar enriched with cowpea flour.

[21] studied the effect of the addition of cowpea on corn flour. Flour mixtures were produced from corn and cowpea flours in the following proportions of corn:cowpea 90:10, 80:20, 70:30, and 100% corn as a control, and the overall result showed that 20% of cowpea substitution was the most adequate percentage to produce a mixture of nutritious and acceptable corn and cowpea flour, which can be useful for pastry and confectionery [21].

Other products fortified with cowpea have been developed, such as cereal bars in technological innovation projects. A patent application filing of a cereal bar enriched with cowpea, cashew fiber, honey, and cashew nuts was made, registration number: BR1020140169873 [67] and a cereal bar enriched with cowpea flour (**Figure 3B**), registration number: BR1020140169792 [68]. These products were accepted by more than 90% of the sensory assessors, which attributed grades between 8 (I really liked) and 9 (I liked very much), demonstrating the potential of acceptance of the products for nutritional interventions in population, both adults and children, to control endemic deficiencies such as iron deficiency anemia.

6. Nutritional interventions with cowpea flour to control iron deficiency anemia

Most studies with nutritional interventions using cowpea flour to control iron deficiency anemia were developed with cowpea fortified with elemental iron, as in the studies of Adom et al. and Abizari et al. [59, 60], but satisfactory results were also obtained with the use of cowpea flour without addition of elemental iron in the control of anemia in children. This can be observed in this same study carried out by Abizari et al. [60], in which an intervention was performed with cowpea meal fortified with iron (NaFeEDTA) and nonfortified cowpea (control group), and it was observed that the group that ingested nonfortified cowpea flour also presented reduction in the prevalence of anemia, iron deficiency, and iron deficiency anemia at the end of the study, showing that the use of cowpea flour alone may be a good strategy in the control of this endemic disease.

In Brazil, Landim et al. [69] conducted an intervention study with 262 preschool children aged 2–5 years attended at municipal Childhood Educational Centers in Teresina, Piauí. One group received cookies prepared with wheat flour fortified with iron and folic acid. The other group received cookies prepared with cowpea flour biofortified with iron and zinc in addition to wheat flour enriched with iron and folic acid (**Figure 4A** and **B**) and noted that both cookies reduced the prevalence of anemia with a larger reduction in the latter group. In addition, a higher increase in hemoglobin levels (12.4–14.7) was observed in the group receiving the cookie prepared with cowpea flour fortified with iron and zinc ($p = 0.003$), whereas the group that received cookies prepared with wheat flour fortified with iron and folic acid showed hemoglobin levels of 12.6 and 12.7 ($p = 0.0754$) before and after the intervention, respectively. The study showed that the use of cookie based on cowpea flour of the biofortified BRS Xiquexique cultivar, as a nutritional intervention proposal, is a viable option because it contains a low cost ingredient, from the habit of the population and that resulted in a product with adequate composition and acceptance by the studied population [69].

The high prevalence of anemia worldwide has warned government institutions and researchers to develop several research studies in an attempt to reduce the numbers and damage, especially

Figure 4. Cookie enriched with cowpea flour of the biofortified BRS Xiquexique cultivar and intervention with preschool children.

to the most vulnerable groups such as children. Drug supplementation has been shown to be effective, but still presents a considerable degree of resistance to the use by children and mothers. Food fortification/enrichment is routinely practiced in several countries and has contributed to reduce the prevalence of anemia, but the biofortification of food as the cowpea, which is produced in countries in Africa and Latin America, including Brazil, where the prevalence of anemia is high, deserves attention because it can be used in the usual form of ingestion (in the form of grains), can be used in the form of flour in the preparation of products for children, with greater acceptance by them, constituting a new and promising strategy to reduce the levels of iron deficiency anemia.

Cowpea is a food that can assist to reduce nutritional endemics, such as iron deficiency anemia, and also improve the quality of the population's diet. It can be used as a raw material in formulations such as snacks, cereal bars, cookies, pizza dough, and various bakery products, in addition to its use in the traditional may as a cooked legume, because it contains nutrients such as proteins, minerals, vitamins, and bioactive compounds.

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