Evaluation of the potential dietary impact of the implementation of nutritionally improved crops in rural areas of the department of Cesar (Colombia)

Evaluación del impacto potencial en la dieta de la aplicación de cultivos mejorados nutricionalmente en zonas rurales del departamento del Cesar (Colombia)

Adriana Tofiño[1, 2], Aslenis Melo R.[3], Yumar Ruidiaz[2], and Sofía Lissbrant[4]

ABSTRACT

In Cesar, 30.7% of children under 5 years of age suffer from deficiencies of vitamin A, along with 13.4% for iron and 57.0% for zinc. Therefore, it is important to guarantee food security in the population through improvements in the nutritional quality of the offered food products. One alternative is the implementation of nutritionally improved crops. The production and consumption of four basic crops in the rural areas of five municipalities were characterized and compared to the implementation of the studied biofortified crops. Surveys regarding the purchase, consumption and production of cassava, bean, maize and rice were given to those responsible for food preparation and/or agricultural production in 90 families and was determined for these food ration consumed per person. In the week prior to the survey, 95.6% of the families consumed bean, 93.3% maize and 88.9% cassava and rice. The products mainly originated from purchases in the local store (bean and rice) or grown by the families (cassava). Cassava and maize were most commonly cultivated (71.1%), followed by bean (56.7%), maize (32.1%), and rice (2.2%). A 61.6% of the cultivated cassava, 23.5% of the maize, and 26.4% of the bean were destined for self-consumption, while the rest was sold or traded. Looking at the difference between the nutritional content of the biofortified products and the traditional and eating habits indicated that the substitution of the traditional varieties with the biofortified crops represented a possible intake increase of 44.59 mg/person-day of iron, 24.05 mg/person-day of zinc, and 1.62 mg/person-day of vitamin A. The substitution with and exclusive consumption of biofortified crops would contribute 199, 169, and 77% iron, zinc, and vitamin A based on the estimated average requirement. Due to their potential nutritional impact, the study of the adaptability and acceptability of biofortified crops is recommended.

Key words: food fortification, human nutrition, food security, family farming, rural communities.

RESUMEN

El 30,7% de niños menores de 5 años del Cesar, presentan deficiencias en ingesta de vitamina A, el 13,4% de hierro y 57,0% de zinc. Por tanto, se hace necesario garantizar la seguridad alimentaria de la población, mediante mejoras en la calidad nutricional de los alimentos ofrecidos. Una alternativa, es implementar cultivos mejorados nutricionalmente. Se caracterizó la producción y consumo de cuatro cultivos básicos, en zonas rurales de cinco municipios, comparándolos con estudios de implementación de cultivos biofortificados. Se encuestaron los encargados de la cocina y/o producción agrícola en 90 familias, sobre compra, consumo y producción de yuca, frijol, maíz, arroz y se determinó para estos la ración consumida por persona. En la última semana, 95,6% de la población encuestada consumió fríjol, 93,3% maíz, y 88,9% yuca y arroz. Los productos derivaron principalmente de la compra en tiendas (fríjol y arroz) y autoproducción (yuca). La yuca y el maíz, se cultivaron en mayor proporción (71,1%), seguidos por fríjol (56,7%), maíz (32,14%) y arroz (2,2%). 61,6% de yuca, 23,5% de maíz, y 26,4% del fríjol cultivados, se destinaron para autoabastecimiento mientras que la producción excedente, para venta o intercambio. A partir de la diferencia entre el contenido nutricional de productos biofortificados y tradicionales y los hábitos alimenticios, se sugiere que la sustitución con productos biofortificados, representa un posible aumento en mg/persona-día de 44,59 de hierro, 24,05 de zinc y 1,62 de vitamina A. La sustitución y consumo exclusivo de biofortificados, aportarían a la requerimiento promedio estimado 199, 169 y 77% más hierro, zinc y vitamina A. Debido al impacto nutricional potencial, se recomienda investigar la adaptabilidad y aceptabilidad de cultivares biofortificados.

Palabras clave: fortificación de alimentos, nutrición humana, seguridad alimentaria, agricultura familiar, comunidades rurales.

Received for publication: 21 July, 2015. Accepted for publication: 17 November, 2015. Doi: 10.15446/agron.colomb.v33n3.51984

[1] Motilonia Research Center, Corporación Colombiana de Investigacion Agropecuaria (Corpoica). Codazzi (Colombia). atofino@corpoica.org.co
[2] Microbiology Program, Faculty of Health, Universidad Popular del Cesar. Valledupar (Colombia).
[3] Assistant Researcher, Agencia de Desarrollo Economico Local del Complejo Cenagoso (ADEL Zapatosa). Valledupar (Colombia).
[4] Observatorio del Caribe Colombiano. Cartagena (Colombia).

Introduction

In an evaluation of food intake performed in Colombia in 2010, it was found that 30.7% of children under 5 years of age that lived in the departments of Guajira, Cesar and Magdalena were at risk of vitamin A deficiencies. Likewise, 57.0% were at risk of zinc deficiencies (ICBF, 2011). Furthermore, it was shown that iron deficiencies (indicated by a low level of serum ferritin) affected 13.4% of the population of the Colombian Caribbean for children between 1 and 4 years of age, 5.2% of children between 5 and 12 years of age, and 19.8% of women between 13 and 49 years of age. Finally, the survey concluded that 58.5% of the households in Cesar, Magdalena, Bolivar, and La Guajira, suffered from food and nutrition insecurity.

Cesar reports 44.8% poverty, surpassing the national average of 30.6% (Cancino *et al.,* 2014). This together with the unemployment rates of rural areas constitute some of the main social problems. A study performed in 12 municipalities in the south of Cesar revealed that, on average, 65% of the families lived under conditions of extreme poverty. Up to 98.1% reported deficiencies for the recommended basic food intake and insufficiencies for iron intake of 34 to 91% and for vitamin A intake of 75 to 96% (Del Castillo *et al.,* 2012). These results agree with the global data, where it is estimated that 75% of the undernourished population lives in rural areas, despite the fact that farming families occupy 80% of the soils used for agriculture (Boy, 2015).

The spread of nutritionally enhanced, high consumption crops aims to decrease the nutritional deficiencies present in the populations of different regions of the planet (García *et al.,* 2011). This process is based on directed crosses with controlled polinization in the field (CIAT, 2011). The use of these improved materials results in the increase of yields per hectare, allows for the promotion of self-consumption by the producers, and lowers the production costs, making it easier for the farmers to place their surplus production in specialized markets (Pachón, 2010). The HarvestPlus project (www.harvestplus.org) increases the concentrations of iron, zinc, and beta-carotene in five crops (bean, maize, cassava, rice and sweet potato) (Harvest plus, 2013; Serrano *et al.,* 2011).

In a study performed in Cauca, the production and actual consumption of crops where nutritionally improved varieties exist were identified as factors that affect the nutritional impact of biofortified crops (Gómez *et al.,* 2010). Additionally, the adaptability of the variety in the cultivated areas, the sensorial acceptability, and the availability of improved seeds are all factors to take into consideration when evaluating the potential impact of biofortified crops.

Due to the high expectations in Cesar related to the registration of two varieties of biofortified bean for the Dry Caribbean coast (Tofiño *et al.,* 2013), it is essential to evaluate the impact of the substitution of traditional varieties with biofortified crops. This information can be used as an indicator of the socio-economic viability of intervention in the rural areas of the mountain range in Cesar. Therefore, this study was performed in order to evaluate: a) the family production and individual consumption of bean, maize, cassava, and rice, b) and the potential nutritional contribution of nutritionally improved varieties, based on the crops cultivated by the families in the area that are destined for self-consumption, and c) compare the results with those found in the department of Cauca.

Materials and methods

The methodology developed by Gómez *et al.* (2010) was applied. A descriptive study was performed between November of 2010 and February of 2011 in order to evaluate the production and consumption of bean, maize, cassava, and rice. The project was approved by the Ethics Committee for Scientific Research of the University of Santander in Bucaramanga. The municipalities included in the study were Curumaní, La Paz, Manaure, San Diego and Pueblo Bello. The families participating in the survey live between 700 and 1,300 m a.s.l. (Rangel-Ch. and Carvajal-Cogollo, 2009; Carbonó-Delahoz and Dib-Diazgranados, 2013). A random sample of 90 of the 180 families participating in the project "Implementation of biofortified bean in the settings of traditional bean production as a nutritional alternative in the food security program of Cesar" was selected. In each family, the person responsible for the food preparation and/or responsible for the production was interviewed. Verbal and written consents were collected and surveys were applied following the ethical aspects defined by the Helsinki Declaration (Kottow, 2014). Based on the results of the surveys, data regarding the weekly frequencies of food consumption of the products included in the study, quantities purchased weekly for family consumption, place of acquisition, and forms of preparation were collected. Also, information was collected regarding the production of the crops, areas destined for each product, cropping systems, associated crops, varieties used, number of production cycles per year, production per semester, and, of this, how much was destined for self-consumption and how much for sell or trading.

Information proposed by Gómez *et al.* (2010) was used in the calculation of the additional supply of minerals and vitamin A from the consumption of nutritionally improved products that would be provided to the diet. For the bean, the average concentrations of iron (80 µg g^{-1}) and zinc (32 µg g^{-1}) measured in the seeds harvested in La Paz Cesar in 2010 were used in the calculations (Tofiño *et al.*, 2011, 2013). Additionally, visits to each residence were performed in order to weigh the portions consumed by all of the family members for a week, using a multifunctional scale for food products (Escali, USA). Given that the portions were not uniform within the families, an average was calculated for each home. Also, the production areas were visited in order to determine the area (using a GPS), planting density, and anticipated yield.

Data analyzes were performed using SPSS v. 11.5. The correlation between the consumed and produced quantities was determined for the cassava, maize, and bean. In addition, the contribution to the Estimated Average Requirement (EAR) for adults, according to the Institute of Medicine of the US National Academy of Sciences, was calculated for iron, zinc, and vitamin A in regards to the consumption of the cassava, maize, and bean (Simpson *et al.,* 2011). The values were corrected; that is to say, the consumption was reduced by a correction factor, according to reports on the postharvest degradation of micronutrients and normal losses of nutrients caused by the processing of raw material for consumption, 10% for iron and zinc and 50% for carotenes (Boy, 2015).

Results

Socio-demographic characteristics of the participants. A total of 160 individuals were interviewed from the 90 households that participated in the survey. Seventy women responded only to the survey regarding consumption and 70 men responded only to the survey regarding production. 15 of the 20 remaining respondents for both activities were women. The women ranged from 19 to 61 years old, with an average of 38 years, and the men were between 20 and 70 years old with an average age of 42.9 years. The level of education ranged from 2 to 11 years for the women (in average 5 years) and between 5 and 11 years (in average 8 years) for the men. The families had, on average, 5.9 persons and the habitants during the last month were approximately 3 persons, between visiting friends and family.

Food consumption: Of the 90 persons in charge of the food preparation, 95.6% reported the consumption of beans, 93.3% consumed maize, and 88.9% consumed cassava and rice during the week before the survey. Also, they indicated that the food products originated from different sources (Tab. 1). The persons consumed rice 6.13 times, cassava 3.8 times, maize 3.65 times, and bean 2.76 times during the week prior to the survey. They also indicated that they purchased, on average, 17.8 kg of cassava, 11 kg of rice, 8.3 kg of maize and 4.1 kg of bean per family for consumption each week. Given the data regarding purchases of food products, cassava was the crop with the greatest consumption per person, with 429.5 g d^{-1}, followed by rice with 265.4 g d^{-1}, maize with 200.3 g d^{-1}, and bean with 98.9 g d^{-1}.

The forms of preparation of the studied food products varied. For example, the bean was mainly prepared as soup, boiled, or in stews; the maize was prepared as *bollos* (boiled corn bun) or *arepas* (corn pancake); and the cassava and rice were boiled All of the food products were used in soup and for arepas although the quantities of maize in the soup and bean in the arepas were small (Tab. 2).

Food production. The second survey was given to the family member in charge of the food production. According to the results, the cassava and maize were the most

TABLE 1. Individual consumption, places of acquisition, and purchased quantities of crops according to the person in charge of the food preparation in families of rural areas of the department of Cesar (Colombia).

Crop	Consumption during the week prior to the survey according to the interviewees		Places and forms of acquisition of the food products destined for family consumption							Weekly consumption per family (kg)
	Consumed product (%)	Consumption frequency (times/week)	Self-production (%)	Trading (%)	Galeria (%)	Store (%)	Granary (%)	Supermarket (%)	Local market (%)	
Bean	95.6	2.76±1.01	40.7	0	3.5	36.1	11.6	1.1	7.0	4.1±3.1
Maize (dry grain)	93.3	3.65±1.65	32.1	1.2	6.0	45.2	13.1	0	2.4	8.3±7.2
Cassava	88.9	3.8±1.51	52.5	2.5	3.7	33.8	5.0	0	2.5	17.8±11.9
Rice	88.9	6.13±1.7	2.5	0	7.5	61.2	20.0	0	8.8	11±2.0

Means±SD (n=90). Some foods were simultaneously purchased by the same family in different places.

TABLE 2. Forms of consumption of the bean, maize, cassava, and rice in families of rural areas of the department of Cesar (Colombia).

Crop	Soup (%)	Boiled (%)	Stew (%)	Soup, boiled and stew (%)	Porridge (*mazamorra*) (%)	Arepas* (%)	Others (%)
Bean	44.2	0	52.3	39.5	0	1.2	2.3
Maize	1.2	27.4	0	2.4	13.1	93.0	13.1
Cassava	30.0	58.7	1.2	6.2	0	2.5	38.7
Rice	16.2	90	3.7	13.7	2.5	5.0	5.0

* Corn is prepared as corn bread or *bollo*. Number of persons participating in the survey (n=90).

TABLE 3. Areas allocated for cultivation, production and quantity destined for consumption of bean, maize and cassava according to the persons participating in the survey regarding production (n=90) of rural areas of the department of Cesar (Colombia).

Crop	Families with established crops (%)	Cultivated area (ha)	Production (kg ha^{-1} per semester)	Production for consumption (kg)
Bean	56.7	1.5±1.6	447.2±201.1	118.8±111.0
Maize	71.1	1.0±1.3	1,601.7±1,137.7	376.0±275.6
Cassava	71.1	0.5±0.2	1,655.2±1,588.7	1,020.2±1,120.6
Rice	2.2	0.2±0.1	NA	NA

Means±SD. NA, not applicable.

commonly cultivated crops (cultivated by 71.1% or 64 of the 90 families), followed by the bean (56.7%), and rice (2.2%) (Tab. 3). The average area per production cycle was 1.5 ha for the bean, 1.0 ha for the maize, 0.5 ha for the cassava, and 0.2 ha for the rice (Tab. 3). The correlations between the consumption and production of the crops were determined as r=0.42 for the cassava, r=0.78 for the maize, and r=0.84 for the bean.

The highest production in the semester prior to the survey was for cassava (1,655.2 kg ha^{-1}), followed by maize (1,601.7 kg ha^{-1}) and bean (447.2 kg ha^{-1}). Seventy-five percent of the bean, 65% of the maize, and 50% of the cassava production were associated with other crops. According to the participants, bean is primarily cultivated with maize (60%), cassava (30%) and plantain (10%), maize is commonly associated with bean (55%), plantain (15%), coffee (20%), and other crops (10%), while cassava is cultivated with coffee (55%), plantain (25%), and bean (20%). Despite the indication of the existence of 7,304 ha of coffee and bean intercropping systems and 10,916 coffee and maize intercropping systems in the area of Perijá and Sierra Nevada in 2011, the data of cropping systems in association with coffee were moderate. In order to promote the diversification of the income sources and improve food security, in 2013, the Colombian Coffee Growers Federation stimulated the establishment of 2,857 ha of maize and 2,203 ha of bean in department of Cesar.

The more commonly cultivated bean varieties were the traditional red bean, chilean (75%), cowpea (15%), and black bean (10%). For maize, yellow maize was the most common (65%) and among the cassava varieties, the more common ones were dwarf (50%) and Venezuelan cassava (40%). Of the total produced amount of these crops in the semester prior to the study, 1,020.2 kg (61.6%) of the cassava, 376.0 kg (23.5%) of the maize, and 118.8 (26.4%) of the bean were destined for self-consumption, while the remainder was sold or traded (Tab. 3).

Potential nutritional contribution from nutritionally improved crops. It was estimated that, if the cultivated cassava, maize and bean destined for self-consumption were substituted with nutritionally improved varieties, this would contribute in each person increase 44.59 mg d^{-1} iron, 24.05 mg d^{-1} zinc, and 1.62 mg d^{-1} vitamin A (Simpson *et al.,* 2011), as compared to what the consumption of non-improved varieties would provide (Tab. 4).

Discussion

The data regarding the production and consumption of the bean, cassava, maize, and rice showed the importance of agriculture in the studied area. Agriculture provides the primary source of employment in the rural areas of Cesar with 62.6% of the population involved in this sector (MADR, 2014) although the contribution to the GDP is less than 5% (Banco de la República, 2012). This indicates that a high percentage of the families in the rural areas cannot generate sufficient proceeds from this sector. The situation is also revealed in the poverty index of 65%, surpassing the average for Latin America (52.8% in rural areas; 27.8% in urban areas), and being comparable to Guatemala with 71.4% poverty in rural areas (Salcedo and Guzmán, 2014).

TABLE 4. Potential contribution of biofortification in the iron (Fe), zinc (Zn), and vitamin A (VA) content of the diet of the families families of rural areas of the department of Cesar (Colombia).

Crop	Production for consumption	Nutrients added to the crops through biofortification			Contribution of additional nutrients through biofortification						Contribution of nutrients from biofortified crops, corrected for degradation due to post-harvest effects and processing **		
	($g\ d^{-1}$ - person)	Fe ($\mu g\ g^{-1}$)	Zn ($\mu g\ g^{-1}$)	VA ($\mu g\ g^{-1}$)	Fe ($\mu g\ g\ d^{-1}$ - person)	Zn ($\mu g\ g\ d^{-1}$ - person)	VA ($\mu g\ g\ d^{-1}$ - person)	EARFe (%)†	EARZn (%)†	EARVA (%)†	EARFe (%)†	EARZn (%)†	EARVA (%)†
Bean	109	80.8±18.4≠	36±1.2≠	NA¥	8,807	3,924	NA	48.9	35.7	NA	44.0	32.1	NA
Maize	348	35	9	1.25‡	12,180	3,132	435	67.7	28.5	48.3	60.9	25.6	24.2
Cassava	944.3	25	18	1.25‡	23,608	16,997	1,180	131.1	154.5	131	94.4	111.2	52.5
Total					44,595∞	24,053∞	1,615∞	247.7	218.7	179.3	199.3	168.9	76.7

* Production for family consumption (kg/semester) multiplied by the number of semesters in a year and grams in one kilogram (1,000) and divided by the average number of family members (5.92), the number of days in a year (365)

≠ For the bean, the values of additional nutrients were obtained from analyses of seeds cultivated in four locations in Cesar between 2008 and 2013 (Tofiño *et al*., 2013).

† Estimated average requirement (EAR) from the USA for adults: 18,000 $\mu g\ d^{-1}$ iron, 11,000 $\mu g\ d^{-1}$ zinc and 900 $\mu g\ d^{-1}$ vitamin A (Simpson *et al*., 2011)

‡ Additional contribution of pro-vitamin A from the maize: 15.0 $\mu g\ g^{-1}$, beta-carotene in the cassava: 15.0 $\mu g\ g^{-1}$. The contribution of pro-vitamin A and beta-carotene was divided by the factor of bioconversion to retinol (García *et al.,* 2011) (12:1) to calculate the contribution to vitamin A.

¥ NA, not applicable.

∞ The values do not exceed the level of daily tolerable consumption provided by the IOM (2010): >45 mg Fe, >40 mg Zn, >3 mg VA.

**Values of EAR were corrected according to the data regarding degradation of micronutrients during post-harvest and food processing: 10% for iron and zinc; and 50% for carotenes (Boy, 2015). In the case of the cassava, the quantity was calculated from 80% of the production, equivalent to the pulp without the peel.

In this country, Harvest Plus is contributing with extensive interventions in order to promote the use of biofortified crops (Del Castillo *et al.,* 2012). This, and considering that a) global food production needs to be doubled by 2050; b) family-scale farmers represent between 80 and 90% of the producers of maize and bean and produce between 75 and 80% of these crops in the world; c) 4,234 t of bean, 126,603 t of rice, 60,615 t of maize, and 36,218 t of cassava were produced in Cesar in 2011 (DANE, 2012); and d) the critical levels of poverty and undernourishment in the rural areas clearly demonstrate the need to propose and drive governmental interventions for the biofortification of crops.

Sociodemographic characteristics. Women have an important role in the production and preparation of the food products because 75% of them are in charge of both activities (data not shown). This value is higher than that of other reports (42.5%) (Marrugo *et al.,* 2015). The average number of family members (5.9) was two more than the average of the department (3.8).

Food consumption. The most commonly consumed crop in terms of weekly consumption (in kg) by family was cassava, followed by rice, maize, and bean. The purchased quantities of these crops exceeded those produced when expressing them as g d^{-1} per person. According to the *Encuesta Nacional de la Situación Nutricional* in Colombia (ENSIN abbreviated in Spanish) (ICBF, 2011), sugar, rice, bread, tubers (cassava and others), bean and maize were found among the food groups with higher consumption the day prior to the survey. The consumption patterns of these four crops were similar to those found in department of Cauca (Gómez *et al.,* 2010) and to the Colombia level (ICBF, 2011). In department of Cesar, however, the consumption of cassava exceeded that of rice because cassava is the most important staple food and together with lactic products constitute the main dish, resulting in high consumption. The bean consumption frequency was similar to that reported in Cauca (Gómez *et al.,* 2010), where more than 90% of the families consumed legumes (mainly bean) one or more times per week. Cassava and rice were consumed with similar frequency, but in higher quantities, as compared to those reported in Cauca (Gómez *et al.,* 2010).

In regards to the origin of the food products, it was observed that the purchased quantities exceeded those produced for self-consumption, except for the cassava. Most of the consumed bean was bought in stores (58.1%) or originated from the family farms (40.7%) (Tab. 1). The numbers were dissimilar in the case of the maize (4.8% and 32.1%, respectively), while the majority of the cassava was produced (52.5%), a large portion was bought in stores (37.5%), and a smaller percentage was obtained by trading (2.5%). Also, the maize was, to a lesser extent, obtained by trading (1.2%). In the case of the rice, the majority was bought in stores (80%) and a smaller part in granaries (20%). Additionally, 2.5% of the farmers indicated that they were currently producing for self-consumption. These numbers corresponded to those reported in the south of Cesar where the primary form of acquisition of calories and nutrients, such as iron, vitamin A, and calcium, was through purchased food (Del Castillo *et al.,* 2012).

Food production. The habit of cultivating maize, bean, and cassava registered in this study was consistent with reports regarding the economic profile of Cesar developed by the MADR e as well as by the *Encuesta Nacional Agropecuaria* of 2011. The positive correlation between the produced and consumed quantities indicated that there was a preference of the farmers to cultivate crops that contribute to the basic food needs.

Potential impact of nutritionally improved crops. If introduced into the region, Harvest plus (CIAT) and Corpoica biofortified varieties could contribute 199% more iron, 169% more zinc, and 77% more of the precursors of vitamin A than the EAR for these nutrients in adults between 19 and 70 years old. These values exceeded those obtained in the study in Cauca, with values that ranged from 10 to 16% (Gómez *et al.,* 2010). This difference was mainly due to the higher occurrence of self-consumption in Cesar. However, the high values should not be a source of concern since they did not surpass the limits of maximum recommended intake of zinc and iron. Also, the retention or assimilation in the body of the nutrients may be lower than the values used in this document, depending on the combination of the food products used in each meal, which affects the final nutrient availability (Boy, 2015).

The projections made in this study are valid assuming that a) a complete substitution of the varieties of the bean, maize, and cassava currently cultivated for self-consumption with nutritionally improved varieties and b) that the annual production destined for consumption in the families remained stable. However, the consumption of cassava estimated in this study corresponded to a diet with carbohydrate intakes exceeding the EAR (130 g d^{-1}) (Simpson *et al.,* 2011), which, among other factors, favored the tendency of obesity in the region (ICBF, 2011). According to reports by the ENSIN 2010, more than 50% of the population in Colombia is overweight (Ortega-Bonilla and Chito-Trujillo, 2014; ICBF, 2011).

Although the risk of overconsumption of carbohydrates should be considered, it is clear that the ingestion of nutritionally improved crops can improve the nutritional status of a population that suffers from deficiencies (ICBF, 2011). Recent studies around the world have registered the effect of the regular consumption of biofortified crops on human health. A study performed in the Philippines showed that the consumption of rice with an elevated iron content contributed 10% of the EAR of iron and raised the serum ferritin and iron levels by 20% (Wenger *et al*., 2014). In India, iron consumption from pearl millet in children between 12 and 16 years was associated with an increase in the serum ferritin and iron concentrations (Wenger *et al.,* 2014). In Ruanda, the consumption of biofortified beans showed significant effects on biochemical indicators such as hemoglobin, serum ferritin and iron, as compared to the control (Boy, 2015). In India, the regular consumption of biofortified pearl millet resulted in an elevated absorption of zinc in pre-school aged children (Gannon, 2014). In pre-schoolers (4 to 8 years old) in rural Mkushi, Zambia, an increased adaptation to penumbra (adaptation to darkness) associated with the consumption of maize with carotenoids was observed. In Cesar, increased levels in ferritin were shown in school children as a result of the consumption of biofortified beans (Tofiño *et al.,* 2012). Additionally, an increased bioavailability of nutrients has been registered in biofortified crops; for example, biofortified wheat provided approximately 70% more bioavailable zinc (in healthy women in Mexico and Switzerland) (Boy, 2015). Furthermore, through the implementation of various products, there may be synergies between the different nutrients that nutritionally improved crops provide. It has been found that commercial sources of vitamin A and beta-carotene supplements promote the absorption of non-heme iron from rice, wheat, and maize (Gannon, 2014).

It would be beneficial to increase the availability of nutritionally improved food products by introducing other traditionally consumed species in the region, such as sweet potato, which constitutes an excellent source of nutrients such as beta-carotene and anthocyanins (Rangel, 2011). Corpoica is currently developing a sweet potato variety with more beta-carotenes for human consumption and is collaborating with Harvest Plus to develop a yellow variety of cassava. These new varieties have the potential of providing carotenes to the diets of the Caribbean coast. In the case of the sweet potato variety, it is estimated to contain 250 mg kg^{-1} of beta-carotene, which means that a consumption per person of 45 g d^{-1} would provide the total EAR. Promoting the consumption of sweet potato in the region would balance the excessive carbohydrate consumption from cassava and, furthermore, the sweet potato has a little more protein than the cassava (Vargas and Hernandez, 2013). The Harvest Plus program (CIAT) is advancing the development of biofortified varieties of upland rice, to be evaluated in the Caribbean region and its communities, in order to strengthen the local markets, the availability of locally produced seeds, and food security programs; given that the primary impact of biofortified crops lies in their availability to vulnerable communities (Vergara *et al.,* 2011). In this context, it is necessary to advance a definition of public policy regarding biofortified crops in Colombia in order to make seeds and products of these varieties available and accessible to the public once they have been released. Panama makes an interesting example because of its policies regarding biofortified crops, implemented despite the fact that the indices of nutritional deficiencies in this country are lower than the Colombian average (Vergara *et al.,* 2011). Although biofortification of bean and cassava appears as a demand defined in the platform Siembra (MADR, n.d.) and makes part of the actions included in the politics of the Ministerio de Salud of Colombia to improve the micronutrient intake (ICBF, 2011), these necessities are still not articulated in the national research centers and the unions, in order to in a sustainable way impact the areas of the country that present high indices of poverty. This document presents a significant impact of diets that include biofortified crops and that are based on the consumption habits of the producers of the mountainous areas of Cesar. It encourages public entities to initiate a plan of action regarding the implementation of biofortified crops, especially for the Caribbean region, where there is a high prevalence of micronutrient and protein deficiencies (Lissbrant, 2015).

Conclusions

Department of Cesar requires governmental intervention in order to implement strategies for the use and consumption of biofortified crops given that it is a producer and consumer of all four crops that have biofortified varieties; it has high indices of micronutrient deficiencies and a percentage of extreme poverty, above 50%. A high correlation between the consumption and production quantities of cassava, maize and bean exists (r =0.42, 0.78 and 0.84, respectively) in the studied area, improving the possibilities of influencing the diet by introducing biofortified varieties in the production. The substitution of crops with biofortified varieties has the potential of significantly increasing the intake of iron, zinc, and vitamin A, without exceeding the tolerable daily intake values. However, additional studies, such as agronomic, nutritional, and sensorial evaluations of biofortified varieties. Besides, the composition and preparation of these products in the diet are needed in order to understand and improve the retention and bioavailability of the nutrients, taking the local gastronomic habits into consideration. It is recommended that the balance of the products evaluated in this study in the diet and in this way decrease the volume of cassava, substituting it for legumes and/or sweet potato.

The results are promising in comparison to those obtained in department of Cauca given destine a larger proportion of their crops to self-consumption. Because of this, the replacement of traditional crops with those that are nutritionally improved, especially cassava and maize, would have an important impact on nutritional indicators. The promotion of public policies by social entities regarding biofortification is needed so that new varieties can reach the vulnerable population.

Literature cited

Banco de la República de Colombia. 2012. Informe de coyuntura económica regional, departamento del Cesar 2012. DANE, Bogota.

Boy, E. 2015. Investigación nutricional de alimentos biofortificados. ¿Qué se ha logrado, y hacia dónde vamos? In: Reunión Anual LX PCCMCA Guatemala, Generación de Tecnología para la Innovación de la Agricultura Intensiva Sostenible. Ciudad de Guatemala, Guatemala.

Cancino, A., G. Meneses, J. Santander, C. Blanco, and A. Villate. 2014. Una mirada al panorama socioeconómico, ambiental y fiscal de la minería del carbón en el Cesar. Civiliz. Empresa Econ. 5, 21-37.

Carbonó-Delahoz, E. and J.C. Dib-Díazgranados. 2013. Plantas medicinales usadas por los Cogui en el río Palomino, Sierra Nevada de Santa Marta (Colombia). Caldasia 35, 333-350.

CIAT, Centro Internacional de Agricultura Tropical. 2011. Combating hidden hunger in Latin America, biofortified crops with improved vitamin A, essential minerals and quality protein. Final report to the Canadian International Development Agency. In: http://ciat-library.ciat.cgiar.org/Articulos_Ciat/2015/69725.pdf; consulted: November, 2015.

DANE, Departamento Administrativo Nacional de Estadística. 2012. Encuesta nacional agropecuaria-ENA 2011. Bogota.

Del Castillo M., S., Z., Fonseca, M. Mantilla, and N. Mendieta. 2012. Estudio para la medición de seguridad alimentaria y nutricional en el Magdalena medio colombiano. Caso Cesar. Rev. Fac. Med. 60, 13-27.

Gannon, B., C. Kaliwile, S.A Arscott, S. Schmaelzle, J. Chileshe, N. Kalungwana, M. Mosonda, K. Pixley, C. Masi, and S.A. Tanumihardjo. 2014. Biofortified orange maize is as efficacious as a vitamin A supplement in Zambian children even in the presence of high liver reserves of vitamin A: a community-based, randomized placebo-controlled trial. Am. J. Clin. Nutr. 100, 1541-1550. Doi: 10.3945/ajcn.114.087379

García M., K.L., J.A. Godoy G., P.M. Carrillo C., and H. Pachón. 2011. Evaluación sensorial de arroz (*Oryza sativa)* variedad Azucena en la Región Autónoma del Atlántico Norte en Nicaragua. Perspect. Nutr. Hum. 13, 135-146.

Gómez G., LK., J. Restrepo, and H. Pachón. 2010. Caracterización del consumo de maíz y fríjol en familias del departamento del Cauca, Colombia. Perspect. Nutr. Hum. 12, 87-98.

ICBF, Instituto Colombiano de Bienestar Familiar. 2011. Encuesta Nacional de la Situación Nutricional en Colombia, 2010. Bogota.

Kottow, M. 2014. De Helsinki a Fortaleza: una declaración desangrada. Rev. Bioét. 22, 28-33. Doi: 10.1590/S1983-80422014000100004

Lissbrant, S. 2015. Seguridad alimentaria y nutricional en la región Caribe: consecuencias de la desnutrición y buenas prácticas como soluciones. Invest. Desarr. 23, 117-138. Doi: 10.14482/indes.23.1.6529

MADR, Ministerio de Agricultura y Desarrollo Rural. 2014. Informe de Rendición Pública de Cuentas Gestión 2013 - 2014. Bogota.

MADR, Ministerio de Agricultura y Desarrollo Rural. n.d. Plataforma Siembra. Consolidado de demandas de la agenda de Hortalizas – Frijol. In: http://www.siembra.gov.co/; consulted: November, 2015.

Marrugo A., C.A., K. Del Risco-Serje, V.C. Marrugo-Arnedo. J.A. Herrera-Llamas, and G.J. Pérez-Valbuena. 2015. Determinantes de la pobreza en la región Caribe colombiana. Rev. Econ. Caribe 15, 47-69.

Ortega-Bonilla, R.A. and D.M. Chito-Trujillo. 2014. Valoración del estado nutricional de la población escolar del municipio de Argelia, Colombia. Rev. Salud Pública 16, 547-559. Doi: 10.15446/rsap.v16n4.40658

Pachón, H. 2010. El impacto nutricional de cultivos biofortificados o cultivos con mayor calidad nutricional. AgroSalud; Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

Rangel, C.N., E.M.M. Silva, L. Salvador, R. Figueiredo, E. Watanabe, J.B.C. Silva, J.L.V. Carvalho, and M.R. Nutti. 2011. Sensory evaluation of cakes prepared with orange-fleshed sweet potato flour (*Ipomoea batatas* L.). Perspect. Nutr. Hum. 13, 203-211.

Rangel-Ch., J.O. and J. Carvajal-Cogollo. 2009. Clima de la Serranía de Perijá. pp. 3-49. In: J.O. Rangel-Ch. (ed.). Media y baja montaña de la Serranía del Perijá. Colombia Diversidad Biótica VIII. Universidad Nacional de Colombia, Bogota.

Salcedo, S. and L. Guzmán. 2014. Agricultura familiar en América Latina y el Caribe: recomendaciones de política. FAO, Santiago.

Serrano R., A.C., E.Y. Vílchez M., C.M. Sandino S., P. Carrillo C., and H. Pachón. 2011. Evaluación sensorial de tortas de camote (*Ipomoea batatas*), elaboradas con o sin hojas de camote, con niños en edad escolar en Nicaragua. Perspect. Nutr. Hum. 13, 191-202.

Simpson, J., L. Baileyb, K. Pietrzikc, B. Shaned, and W. Holzgrevee. 2011. Micronutrients and women of reproductive potential: required dietary intake and consequences of dietary deficienty or excess. Part II - vitamin D, vitamin A, iron, zinc, iodine, essential fatty acids. J. Matern. Fetal Neonatal Med. 24, 1-24. Doi: 10.3109/14767051003678226

Tofiño, A., R. Tofiño, and H. Jiménez. 2012. Determinación del potencial productivo y nutricional de un fríjol biofortificado mesoamericano en el Cesar, Colombia. Vitae 19(Suppl. 1), 297-299.

Tofiño, A.P., R. Tofiño, and S. Lissbrant. 2013. Contribution of the meso american biofortified bean (*Phaseolus vulgaris* L.) to food security and competitiveness in the agronomic production chain in the Caribbean coast of Colombia. Annu. Rep. Bean Improv. Coop. 56, 11-12.

Tofiño, A., R. Tofiño, D. Cabal, A. Melo, W. Camarillo, and H. Pachón. 2011. Evaluación agronómica y sensorial de fríjol (*Phaseolus vulgaris* L.) mejorado nutricionalmente en el norte del departamento del Cesar, Colombia. Perspect. Nutr. Hum. 13, 161-177.

Vargas A., P. and D. Hernández V. 2013. Harinas y almidones de yuca, ñame, camote y ñampí: propiedades funcionales y posibles aplicaciones en la industria alimentaria. Tecnol. Marcha 26, 37-45. Doi: 10.18845/tm.v26i1.1120

Vergara, O., I. Camargo B., T. Henríquez, E. Vergara de Caballero, E. Mojica de Torres, J. Espinosa, and S. Montenegro 2011. Evaluación sensorial del arroz biofortificado, variedad IDIAP Santa Cruz 11, en granjas autosostenibles del Patronato de Nutrición en la Provincia de Coclé, Panamá. Perspect. Nutr. Hum. 13, 147-160.

Wenger, M., S. Scott, L. Murray-Kolb, E. Cooper, P. Ghugre, S. Udipi, and J. Haas. 2014. Changes in brain dynamics as a function of changes in body iron status: effects on attentional function in Indian adolescents following consumption of iron-biofortified pearl millet (389.2). FASEB J. 28, 389.2.