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Influence of hydrothermal treatment on physicochemical characteristics of white beans seeds (*Phaseolus vulgaris*) produced in Côte d'Ivoire.

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ABSTRACT

Objective: Beans are eaten after cooking and the cooking methods significantly affect their biochemical composition. In this study, the effect of traditional cooking methods such as boiling and steaming on the nutritional composition and anti-nutritional factors in white beans (*Phaseolus vulgaris*) was investigated.

Methodology and Results: In both cooked and uncooked white beans, proximate composition and anti-nutritional components were determined according to standard methods. The results showed that cooking treatments decreased the nutritional and anti-nutritional composition in white beans. Boiling decreased the dry matter, ash, lipid, total carbohydrate and protein, with an average loss of 65.98 %; 31.18 %, 39.37 %; 83.42 % and 37.50 % respectively. The losses due to steaming were smaller than boiling with the values of 39.20 %, 13.06 %, 10.31 %, 54.94 % and 13.17 % respectively for the dry matter, ash, protein, lipid and reducing sugars. Excepted for phytates where losses due to steaming are slightly higher (6.38 %) compared to those of boiling (5.42 %), boiling induced higher losses on anti-nutritional composition such us total oxalates (62.88 %) and phenols (81.95 %) compared to steaming, which caused only of the less significant losses of 38.18 % and 73.42 % respectively.

Conclusion and application of results. As shown in this study steaming and boiling cooking affect the composition of white bean. They induce a loss in nutritional compounds and anti-nutritional factors in the bean. However, steaming of white bean caused slight losses in nutritional composition and antinutritional factors than boiling. Steaming could be recommended in infant feeding because it preserves nutrients necessary for their development

Keywords: hydrothermal, steaming, boiling, white bean seed, losses, Côte d'Ivoire

INTRODUCTION

Like most developing countries, Côte d'Ivoire has a deficit in national production of animal protein for a population whose main protein source is animal (FAO, 2008). Côte d'Ivoire is also affected by the rapid population growth these recent years (Fondio *et al.,* 2013). The Ivorian economy is essentially based on agriculture. However, despite the many efforts made by the State of Côte d'Ivoire, the problems of undernourishment are increasing. About 12.6 % of rural households are food insecure according to the Ministry of Agriculture & FAO (2009). In addition, protein-energy malnutrition (PEM) is the cause of more than one-third of child deaths (Black, 2008). Worldwide, one in three children under five years suffer from protein energy malnutrition (WHO, 2000). The severe form affects more than one billion people, 99 % of whom are in developing countries (FAO, 2009). Amoikon *et al* (2016) reported that stunting is the type of malnutrition that affects many children from 0 to 59 months, with a rate of 14.78 %. To meet their food needs, rural African people supplement subsistence farming with wild edible species such as grain legumes (FAO, 1988). Among legumes, beans are an important source of vegetable protein for human consumption (Kellouche & Soltani, 2005). They have been recognized as one of the best and cheapest foods for people in developing countries (Young & Pelett, 1994). The common bean (*Phaseolus vulgaris*) belongs to the large group of legumes. Like meat, fish and mushrooms, white common beans are an important source of dietary protein. The most consumed varieties of beans are the red and white varieties (Kinyanjui *et al*., 2015, Njoroge *et al*., 2015), with annual production and consumption rates of 4800 tonnes and 97.50 g / person / day (FAOSTAT, 2013). In addition to their high protein content, dried beans (*Phaseolus vulgaris L.*) are a good source of carbohydrates, vitamins and minerals. These characteristics make bean, a good nutritional value. However, the nutritional quality of beans is highly influenced by factors like cooking modes. In fact, cooking caused the losses of certain nutrients, either by the diffusion of water-soluble constituents in the cooking water, or by the destruction of thermolabile substances (Rocca-Poliméni, 2007). Cooking of white beans by steaming has not been extensively studied but it has been shown to reduce antinutritive agents in soybean (Rajko *et al.*, 1997) and have positive effects on protein digestibility (Khatoon and Prakash, 2004) in whole legumes. A study on white bean cooked by steaming is thus needed to know whether this treatment could improve nutritional quality and eventually replace traditional cooking methods, which cause important losses in nutrients. Thus, the objective of this study was to investigate the effect of hydrothermal treatment on the physicochemical characteristics of white beans seeds (*Phaseolus vulgaris*).

MATERIAL AND METHODS

Material: Five (5) kg of white bean (*Phaseolus vulgaris*) were collected at maturity in experimental farm at Nangui Abrogoua University (Abidjan/ Côte d'Ivoire). Seeds were sun-dried for a week, hand-sorted to remove wrinkled, moldy seeds and foreign material like dry leaves or stones. The dried beans were divided into three equal portions (1 kg) in which the first part was ground uncooked and used as control, the second one was steamed and the third one was boiled.

Preparation of uncooked and cooked bean samples: The raw bean flour of *Phaseolus vulgaris L.* was prepared using the method described by Kinyanjui *et al.* (2015). Boiled seeds were prepared according to the method of Audu and Aremu (2011), with slight modifications. In fact, 100 g of beans was boiled in water at 100°C for 3 h at the ratio of 1:14 (w/v). The seeds were considered boiled when the endosperms were easily crushed by a gentle press between the thumb and index fingers. As for steaming, the grains were cooked to the same extent as the boiling cooking at the ratio of 1:14 (w/v). The grains are placed in a stainless-steel couscous pot, which was placed above the container containing the boiling water. The boiled and steamed beans were allowed to cool, oven-dried at 40°C for 7 h, ground into flour by a hammer mill model 303 SAP, passed through a sieve of aperture size <300 mm and packed into labelled capped bottle. Flours were used for proximate and antinutrients determination.

Chemical composition of raw and cooked bean: AOAC (1990) methods were used for moisture, ash, crude fibre, protein and carbohydrate contents determination. Moisture was determined by heating 2 g of sample to a constant weight in a crucible placed in an oven maintained at 105°C. Ash was determined by incineration of 1.5 g of samples placed in a muffle furnace maintained at 550°C for 6 h. Protein was quantified by Kjedahl method using 2 g of samples where total nitrogen was determined and then crude protein was calculated as % total nitrogen × 6.25. The reducing sugar content is determined according to the technique described by (Miller, 1959) using 3, 5-dinitrosalicylic acid (DNS). Lipid was extracted in 10 g of sample in a soxhlet apparatus using hexane as solvent as described by the BIPEA (1976) method. Carbohydrate was calculated by difference. The energy values were calculated using the conversion factor provided by Food and Agricultural Organization (FAO, 2003). Phytate was extracted and separated by ion-exchange chromatography according to the method of AOAC (2000) before being quantified colorimetrically using an Ultraspec 3000 spectrophotometer at 500 nm (Latta and Eskin, 1980). The total phenolic content of beans was determined using the Folin-Ciocalteu colorimetric method, as described by Gao *et al* (2000). Total phenolic content of samples was determined using gallic acid standard curve and the results were expressed as mg of gallic acid equivalents per gram (GAE/g) of sample. The raw and cooked beans samples were analyzed for content of Oxalate according to the methodology described by Day and Underwood (1986). The rate of loss of biochemical compounds was calculated as a ratio of their amount before cooking minus after cooking by their content before cooking, the whole multiplied by 100 (Nikmaram *et al*., 2011).

$$\text{Cook loss} = \frac{\text{Weight of raw sample} - \text{Weight of cooked sample}}{\text{Weight of raw sample}} \times 100$$

Data Analysis: Analyzes were made in triplicate and the mentioned values were the average ± standard deviation (SD). These experimental data were subjected to Analysis of Variance (ANOVA) and Duncan's multiple range test for mean separation at p<0.05 in STATISTICA software version 7.1.

RESULTS

Nutritional composition of bean seeds: The nutritional composition of cooked and uncooked white bean seeds is shown in Table 1 and the rate of nutrients loss in Figure 1. Dry matter of the three samples are statistically different (p<0.05) with the values of 90.59 ± 0.922 g/100g; 30.81 ± 0.492 g/100g; 55.07 ± 0.750 g/100g respectively for uncooked, boiled and steamed beans (Table 1). However, the dry matter of boiled seeds was lower than those of steamed and uncooked seeds with the losses in boiling and steaming of 31.18 % and 13.06 % respectively (Figure 1). The protein content was 23.315 ± 1.421 g/100g in uncooked bean and ranged from 20.91 ± 0.127 g/100g to 14.57 ± 0.806 g/100g in steamed and boiled beans (Table 1) with significant losses of 37.50 % and 10.31 % respectively (Figure 1). The ash in uncooked white bean (5.13 ± 0.21 g/100g) was significantly higher (P<0.05) than those of steamed seeds (4.46 ± 0.381 g/100g) which one was also significantly higher than those of boiled seeds (3.53 ± 0.21 g/100g). Table 1 shows the reducing sugars contents of the white beans samples. Reducing sugar content ranged from 8.65 ± 2.357 mg/100g; 7.57 ± 1.051 to 2.73 ± 0.127 mg/100g, respectively for uncooked beans, boiled beans and steamed beans. However, the reducing sugars content decreased significantly (P<0.05) in beans after boiled and steamed with the losses in boiling and steaming of 13.17 % and 68.43 % respectively for steaming and boiling. Boiling had different carbohydrate values, which were significantly lower than that of steaming cooked and raw samples. Furthermore, the calorific values obtained from raw (369.18 ± 0.261 kcal/100g), boiled (125.67 ± 0.581 kcal/100g) and steamed samples were significantly different (223.19 ± 0.342 kcal/100g) (P<0.05). The caloric values of boiled seeds was lower than steamed and uncooked seeds with significant losses (P<0.05) of (65.95 %) and (39.54 %.) respectively.

Table 1: Effect of cooking methods on the chemical composition of white beans seeds (*Phaseolus vulgaris*).

Parameters	Uncooked beans	Boiled beans	Steamed beans
Dry matter (g/100g)	90.59 ± 0.922^c	30.81 ± 0.492^a	55.07 ± 0.750^b
Ash (g/100g)	5.13 ± 0.208^c	3.53 ± 0.208^a	4.46 ± 0.381^b
Protein (g/100g)	23.315 ± 1.421^b	14.57 ± 0.806^a	20.91 ± 0.127^b
Fat (g/100g)	5.46 ± 0.130^c	3.31 ± 0.228^a	4.15 ± 0.05^b
Reducing sugars (mg/100g)	8.65 ± 2.357^c	2.73 ± 0.127^a	7.57 ± 1.051^b
Flavonoid (mg/100g)	5.85 ± 0.056^c	0.725 ± 0.128^a	1.770 ± 0.106^b
Total carbohydrate(g/100g)	56.695 ± 0.59^c	9.4 ± 0.036^a	25.55 ± 1.10^b
Energy values (kcal/100g)	369.18 ± 0.261^c	125.67 ± 0.581^a	223.19 ± 0.342^b

Means in the same column with different letters are significantly (P<0.05) different. Means ± standard deviation

Flavonoid contents were significatively different ($P<0.05$) in all white beans samples with the values of 5.85 ± 0.056 mg/100g; 0.725 ± 0.128 mg/100g and 1.770 ± 0,106 mg/100g respectively for uncooked, boiled and steamed beans (Table 1). The losses in flavonoid are highest with boiled beans (87.61 %) than steamed beans (69.74 %) (Figure 1).

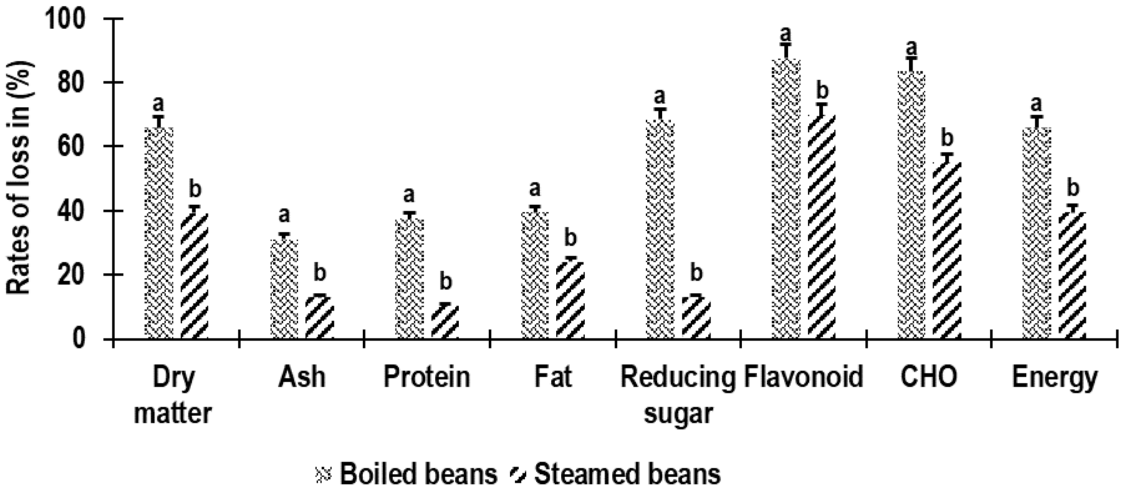

Figure 1: Rates of loss of nutritional compound in white beans seeds (*Phaseolus Vulgaris*). CHO= Carbohydrate

Antinutritional composition of bean seeds: The antinutritional composition of cooked and uncooked white bean seeds is shown in Table 2 and the rate of antinutrients loss in Figure 2. Table 1 revealed that the content of phytic acid in raw sample had significant difference ($P<0.05$) with both sample (boiled and cooked sample) with the values of 57 ± 0.173 mg/100g, 53.91 ± 2.304mg/100g and 53.36 ± 0.342 mg/100g respectively for uncooked, boiled and steamed beans. However not different observed. However, no significant difference ($P< 0.05$) was observed between losses of phytic acid from boiled beans and steamed beans (Figure 2). The amount of oxalate in all hydrothermal treatments decreased significantly ($P<0.05$). Table 2 indicated that oxalate content in raw sample is higher (0.644 ± 0.048 mg/100g) than those boiled (0.239 ± 0.073 mg/100g) and steamed (0.398 ± 0.023 mg/100g) sample. It was observed on the Figure 2 that boiled beans seeds shows high losses than steamed beans with the values of (62.89 %) and (38.20 %) respectively. Total phenol contents were significatively different ($P<0.05$) in all white beans samples with the values of 298.56 ± 0.992 mg/100g; 79.35±0.000 mg/100g and 53.89±0.57mg/100g respectively for uncooked, boiled and steamed beans (Table 2). Furthermore Figure 2 shown significant losses ($P<0.05$) of 81.95 % and 73.42 % respectively in steamed and boiled beans.

Table 2: Effect of cooking methods on antinutritional factors of white beans seeds (*Phaseolus Vulgaris*) (mg/100g fresh mater)

Parameters	Raw	Boiling	Steaming
Total phenol	298.56 ± 0.992 ^{c}	79.35 ±0.000 ^{b}	53.89 ± 0.57 ^{a}
Phytate	57 ± 0.173 ^{b}	53.91 ± 2.304 ^{a}	53.36 ± 0.342 ^{a}
Oxalate	0.644 ± 0.048 ^{c}	0.239 ± 0.073 ^{a}	0.398 ± 0.023 ^{b}

Means in the same column with different letters are significantly ($P<0.05$) different. Means ± standard deviation.

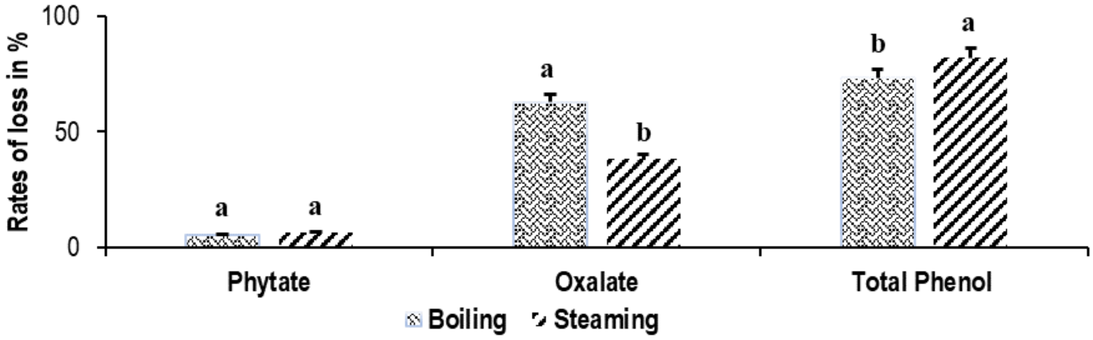

Figure 2: Rates of loss of antinutritional factor in white beans seeds (*Phaseolus Vulgaris*)

DISCUSSION

The moisture content of boiled beans was significantly higher ($P<0.05$) than those steamed. This result indicated higher level of water activity in boiled samples, which plays a vital role in food storage (Gao *et al.*, 2000). Cooking caused a significant decrease in dry mater content for the seeds. Similar results were obtained by Shah *et al* (2011). These decreases might be attributed to their diffusion into cooking water (Hefnawy, 2011). The steamed beans had the highest values of crude protein (20.91 %), and crude fat (4.15 %) while boiled white beans had the least values of crude protein (14.57 %), crude fat (3.31 %). This result was in agreement with the report by Omenna *et al* (2016). There was also comparable value in the ash content of raw sample and steamed beans treated samples except the boiled beans, which had less. In general cooking significantly ($P<0.05$) reduced the protein content of white bean. The reduction in protein content could be attributed to partial removal of certain amino acids, along with other nitrogenous compounds, on heating as has been reported by Ranjani (2009). The results obtained indicated that about 39.37 % and 23.99 % of fat content on white beans are significantly ($P<0.05$) lost respectively after boiling and steaming cooking. These observations are in agreement with those reported by Abusin *et al*. (2009). This finding agreed with reports by Soetan and Oyewole (2009) that cooking treatment caused significant ($P<0.05$) decrease in fat and ash. (Figure 1) shows carbohydrates and caloric values of raw and cooked dry beans seeds. White beans are not only a good source of protein but also offers substantial amount of carbohydrate (226.78 g/100g) and calorific values (369.18 kcal/100g). However, results indicated higher losses of carbohydrate and caloric value in boiled seeds (83.42 %) than steamed seeds (54.93 %) due to the high solubility of carbohydrate and their diffusion into cooking water (Hefnawy; 2011). Reducing sugars are significantly ($P<0.05$) reduced. The highest reduction was noted after boiling (68.43 %) while the less loss of reducing sugars was observed when white beans were steamed (13,17 %) (Juajun *et al.*, 2012). These reductions are presumably due to their diffusion into cooking water. Like nutritional compounds, the antinutritional factors in dry bean grains decrease with cooking. The cooking process can modify the physicochemical characteristics of legumes by considerably reducing the antinutritional factors naturally present. Dry white beans are characterized by their high phytate content (57 ± 0.173 mg/100g). Similar results were obtained by Hefnawy (2011) and Abusin *et al*. (2009). The high losses caused by steaming can be explained by the steaming time, which is longer than boiling cooking according to studies by Kinyanjui *et al*. (2015). The decreases of oxalate (62 % with boiling and 38 % with steaming) might be attributed to their diffusion into cooking water Hefnawy (2011). Oxalates and phytates are antinutritional factors that interfere with the bioavailability of minerals such as calcium, magnesium, zinc and iron (Hassan *et al*., 2011). Total polyphenols have an inhibitory activity on digestive enzymes by complexing with proteins (Carnovale *et al*., 1991). The decrease of total polyphenol content (73.42 % - 81.95 %) could be the consequence of a destruction of the cellular structure during cooking. The cells swell and explode in the presence of an excess of water during the cooking then releasing their contents. The losses due to steam cooking could be explained by a long cooking time (Abusin *et al.,* 2009).

CONCLUSION

This study showed that hydrothermals processing as boiling and steaming cooking, caused the loss of nutrients, this might be due to leaching during heat application. It was noted a significant reduction of nutrient and anti-nutrients content of white beans after boiling and steaming cooking. This probably is because the anti-nutrients are heat labile. However, steaming cooking caused slight losses in nutrients, while boiling caused significant losses. The adoption of steaming cooking of the white bean seed in the food practices should be privileged.

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