INNOVATIONS IN CASHEW PRODUCTION

1st ACA Research Proceeding
2022 Edition

USDA
PRO-Cashew
WEST AFRICA CASHEW PROJECT
CNFA
Cultivating New Frontiers in Agriculture
ACA

LIST OF REVIEWERS

Osei Akoto - Director, Crop Services Directorate, MOFA

Dr. Esther Gyedu-Akoto - Physio/Biochemistry, CRIG

Ms Margaret Aduama Larbi - Physio/Biochemistry, CRIG

Dr. Paul Adu-Gyamfi - Plant Breeding, CRIG

Dr. Ishmael Amoako- Attah - Plant Pathology, CRIG

Dr. Sampson Konlan - Agronomy, CRIG

Dr. Alfred Arthur - Soil Science, CRIG

Dr. Evelyn Ahiale - Social Science and Statistics Unit, CRIG

Terra Nyarko - Social Science and Statistics Unit, CRIG

Kofi Appiah Nuamah - ICT/secretary

Contents

COMPLEMENTARY EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON THE GROWTH OF YOUNG CASHEW (*ANACARDIUM OCCIDENTALE L.*) IN TWO AGRO-ECOLOGIES OF GHANA

A. Arthur*, J. A. Dogbatse, P. K. Adu-Gyamfi and F. K. Padi

Cocoa Research Institute of Ghana, P.O. Box 8, New Tafo-Akim

*Corresponding author: alfredarthur76@yahoo.com

Abstract

Cashew cultivation has received enormous attention in recent years due to its economic potential. The cultivation of the crop is, however, usually without soil amendments. This study was, therefore, carried out to compare the effects of complementary and sole applications of organic and inorganic fertilizers on the growth performance of newly transplanted cashew seedlings. The study was carried out at Bole in the Guinea Savannah and Nkonsia in the Forest Transitional agro-ecologies of Ghana from 2017 to 2019. The soil at Bole is classified as an Acrisol while that of Nkonsia as a Lixisol. The soils at both locations were slightly acidic with low levels of organic carbon and total nitrogen. Available phosphorus was very low at Bole but high at Nkonsia. The treatments tested were two rates of inorganic fertilizer (NPK 20-10-10), and two rates of organic fertilizer (poultry manure) with 2.50% N, 1.19% P and 1.20% K. The inorganic fertilizer (NPK 20-10-10) was applied at 50 g and 100 g/seedling/year. The organic fertilizer (poultry manure) was applied at 400 g and 800 g/seedling/year. The complementary application was 25 g (NPK 20-10-10) + 200 g (poultry manure)/seedling/year and 50 g (NPK 20-10-10) + 400 g (poultry manure)/seedling/year. There was a no-fertilizer control treatment. The two applied rates of the fertilizers were to provide 10 g and 20 g N, respectively. The experiment was laid out in a randomized complete block design with three replications. After two years of establishment, cashew stem diameter was not significantly ($p>0.05$) influenced by the various fertilizer treatments at both locations. Plant height was significantly ($p<0.05$) taller under the 100 g (NPK 20-10-10) and 50 g (NPK 20-10-10) + 400 g (poultry manure) treatments at Bole. At Nkonsia, a significantly ($p<0.05$) taller plant was produced under the 400 g (poultry manure) treatment. Complementary application of inorganic and organic fertilizers produced more vigorous plants at Bole while sole organic fertilizer produced more vigorous plants at Nkonsia. It is therefore, concluded that complementary application of 50 g (NPK 20-10-10) + 400 g (poultry manure)/seedling/year or sole application of 400 g (poultry manure)/ seedling/year could be applied to enhance the growth of young cashew seedlings in Ghana.

Keywords: Inorganic fertilizer, Organic fertilizer, Complementary application, cashew

1.0 Introduction

Cashew (Anacardium occidentale L.) is an important cash crop grown principally for its nuts. The edible kennel is highly valued as a food and is widely used in confectionery. Erroneously, the cashew is considered to require low levels of plant available nutrients because many plantations are found in soils of low natural fertility to which no fertilizers are applied. Harvesting of cashew nuts and apples gradually depletes the soil of plant nutrients. For example, the essential nutrient loss attributable to the removal of 1 kg of cashew (nuts plus apple) is estimated to be about 64.0, 2.0 and 25.0 g N, P, K respectively (Bhaskar et al., 1995) and these translate into huge amounts per hectare. These nutrients can be returned to the soil through fertilizer applications. The application of inorganic fertilizers significantly increased the growth and yield of cashew in major producing countries (Ghosh, 1989; Grundon, 1999). However, in Ghana, the usual practice is to remove cashew apples and nuts without soil nutrient replacement. The use of inorganic fertilizers to supply the needed amount of nutrients to cashew is presently expensive for farmers. Similarly, these nutrients are often not supplied due to the scarcity of fertilizers. Furthermore, continuous usage of inorganic fertilizers alone affects soil health resulting in decreased soil productivity (Macit et al., 2007). However, the use of inorganic fertilizers in cashew cultivation cannot be ruled out completely.

The application of inorganic fertilizers in highly leached and weathered soils as found in Ghana would adversely affect cashew growth and yield due to poor soil physical structure and nutrient retention characteristics. Furthermore, these fertilizers pose a chronic problem in terms of their cost (Kotschi, 2013) and deterioration in soil physical, chemical and biological properties (Bibi et al., 2010) that urge sustainable options. The application of organic fertilizer such as poultry manure (PM) which is cheap and environmentally friendly has tremendous potential for reducing the over dependence on inorganic fertilizers. PM is organic manure which abounds in the peri-urban areas of Ghana. The manure so produced is disposed of in several ways, including burning. However, some farmers are aware of the beneficial effects of PM and its release of nutrients for a good response in plant growth. It has been revealed from some studies that organic fertilizers improve soil physical properties such as bulk density and porosity, help the soil to maintain better tilth and increase water holding capacity (Abbasi et al., 2002; Ogunwale et al., 2002; Dauda et al., 2008). Organic fertilizer supplies both major and minor plant nutrients and the supplied nutrient can substitute substantial amounts of inorganic fertilizer (Tollesa, 1999). Organic fertilizers are capable of building up soil fertility and increasing crop yield (Yaduvanshi, 2003; Akoun, 2004). Some studies reported that the improvement of soil fertility under low input agricultural systems requires the input of organic materials (Palm et al., 2001; Soumare et al., 2003).

Nonetheless, sole organic fertilizer and inorganic fertilizer applications are unable to give economic yield and do not sustain productivity under continuous intensive cropping. The use of organic fertilizers together with inorganic fertilizers in terms of balanced nutrient supply (Khan et al., 2008), compared with the sole application of organic or inorganic fertilizer, had a higher positive effect on soil health and crop yields (Ayeni, et al., 2009; Ewulo, et al., 2009; Onasanya et al., 2009). Application of organic manure in combination with inorganic fertilizer has been reported to increase absorption of N, P and K in the plant, compared to either inorganic fertilizers or organic fertilizers alone (Bokhtiar and Sakurai, 2005; Dutta et al., 2003).

The combined application of organic and inorganic fertilizers has received considerable attention in food crop production. This approach to crop nutrient management will be more suitable for cashew farmers because it will reduce the application of inorganic fertilizers, the cost of cultivation as well as increase nutrient management options. However, a study on combined nutrient management in cashew production has not yet been conducted in Ghana. Since inorganic fertilizers are scarce and costly while the cost of organic fertilizers is low and has long lasting effects, it is pertinent to study the effects of complementary use of inorganic and organic fertilizers. Therefore, the objective of this study was to investigate the effects of organic and inorganic fertilizers either alone or in combinations on the growth of newly transplanted cashew seedlings.

2.0 Materials and methods

2.1 Study sites:

The study was carried out at Bole in the Guinea Savannah and Nkonsia in the Forest Transitional agro-ecologies of Ghana from 2017 to 2019.

2.2 Experimental design and treatments:

A randomized complete block design with three replicates was used for the experiment. The organic fertilizer used was PM collected from layer birds in a deep litter system and decomposed for 2-months. The inorganic fertilizer was NPK 20-10-10. Seven treatments consisted of two rates of inorganic fertilizer (NPK 20-10-10), two rates of organic fertilizer PM, two combinations of organic and inorganic fertilizer and a non-fertilized control. The inorganic fertilizer was applied at 50 g and 100 g/seedling/year and the organic fertilizer at 400 g and 800 g/ seedling/year. The complementary application was 25 g (NPK) + 200 g PM/seedling/year and 50 g (NPK) + 400 g PM/seedling/year and the no fertilizer control treatment. The two applied rates of the fertilizers were to provide 10 g and 20 g N, respectively. The soil amendments (both NPK and PM) were applied once per year. The treatments were ring applied and mixed into the topsoil at the dripline of each plant (0.1 to 0.2 m from the base of the plant).

2.3 Plot establishment and husbandry:

The plot was planted with six elite cashew materials in September 2017. Six-month-old cashew seedlings previously raised in a nursery were transplanted to the field at a spacing of 10 × 10 m (equivalent to 100 plants ha−1). The interspaces were planted with maize and groundnut to ensure maximum utilization of the land. Weeds were controlled manually when necessary, during the study period in order to avoid competition with the cashew plants.

2.4 Poultry manure and soil analyses

Soil samples were collected at two distinct depths of 0-15 cm and 15-30 cm before establishing the plots. The soil samples collected were placed in polybags, labelled properly and sent to the laboratory for the determination of physico-chemical properties. The samples were air-dried, ground and passed through a 2 mm mesh sieve and kept for analyses. The soil pH was determined using Suntex pH/Temp (SP-701) meter in a soil: water ratio of 1:2.5. Soil organic carbon was determined using the modified Walkley and Black wet oxidation method. Soil total N was determined using the Kjeldahl digestion and distillation method, while available P was determined by the Troug method. Exchangeable Ca, K, and Mg were extracted with 1 N ammonium acetate solution, and the concentrations were determined using the Atomic Absorption Spectrophotometer (Varian Spectr AA 220 FS). The hydrometer method was used to determine the relative proportions of sand, silt, and clay. All methods were referred to Sparks et al. (1996). The PM samples were also analysed for chemical properties using some of the standard methods for soil analyses. However, total phosphorus was determined by double acid wet digestion method using a 2 :1 (v/v) nitric : perchloric acids ratio (AOAC, 1990) and colorimetrically on a spectrophotometer, and total K, Mg, and Ca were determined by double acid wet digestion method using 2 :1 (v/v) nitric : perchloric acids ratio (AOAC, 1990), followed by atomic absorption spectrometry. All measurements were carried out at the Soil Science Laboratory of the Cocoa Research Institute of Ghana.

2.5 Growth Data:

The traits evaluated with respect to growth were plant height, stem diameter and plant vigour. These growth data were taken on five cashew plants for each treatment that is replicated three times. One month after transplanting and prior to the commencement of treatment application in September 2017, the height of each seedling was measured with a meter rule from the soil surface to the apex of the plant. Stem diameter at a height of 10 cm from the soil surface was measured with digital calipers. Subsequent seedling height and stem diameter measurements were taken at six-month intervals until September 2019, following the same procedures.

2.6 Statistical Analysis:

Data collected on plant growth characteristics were subjected to analysis of variance (ANOVA). Treatment means that show significant differences were compared using the standard error of difference (SED). All statistics were performed using GenStat statistical package (edition 12, Lawes Agricultural Trust, Rothamsted Experimental Station, http://www.vsni.co.uk).

3.0 Results and Discussion

3.1 Chemical characteristics of the poultry manure:

The PM had properties consistent with those used by other researchers in Ghana and elsewhere (Agbede and Adekiya, 2016; Agyenim-Boateng et al., 2006; Dogbatse et al., 2021; Mitchell and Donald, 1995). The PM used was generally high in the major nutrients. The pH and C:N ratio values were also good indicators of quality manure (Table 1).

Table 1: Some chemical properties of poultry manure (PM) used in the study

Manure	Organic C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	pH	C/N
PM	22.5	2.50	1.19	1.20	0.81	0.56	6.6	9.0

Location	Soil Depth (cm)	pH	Org C (%)	Total N(%)	Avail. P (mg kg-1)	Exch. K	Exch. Mg	Exch. Ca
							cmol kg-1	
Bole	0 -- 15	6.37	1.12	0.05	2.76	0.19	1.13	1.61
	15 -- 30	6.35	0.87	0.03	1.43	0.12	0.87	1.06
Nkonsia	0 -- 15	6.05	1.17	0.11	15.82	0.30	2.10	2.55
	15 -- 30	5.94	0.77	0.09	13.47	0.28	1.80	2.04

3.2 Status of soil nutrients:

The soil pH values recorded at Bole for both depths (6.37 and 6.35) and those obtained at Nkonsia (6.05 and 5.94) were slightly acidic. These pH values are, however, suitable for the cashew crop, since it has a wide range of tolerance from pH 4.5-8.5 while optimum values are within 5.2-7.5 (Dedzoe et al., 2001). Soil organic carbon (SOC) for the two depths at both locations was below the critical value of >2% considered suitable for cashew cultivation (Table 2). The total nitrogen content of the cashew soils except for the topsoil at Nkonsia was below the 0.1% N required for cashew cultivation (Aikpokpodion et al., 2010). The low N content could be due to the low organic matter content of the soil. Hence it is expected that the application of organic fertilizer materials would enhance soil fertility and the performance of cashew trees. The calcium content of the soil recorded from the two locations was above 0.8 cmol kg-1 which is the critical value for ideal soils for cashew. Soil potassium and magnesium recorded at the two sites for both soil depths were within the critical values of 0.12 cmol kg-1 and 0.08 cmol kg-1, respectively. Available P contents of soil at Bole were generally low for optimum cashew cultivation while that of Nkonsia was above the optimum value of 10 mg kg-1

Table 2: Some selected soil chemical properties at the two study sites

3.3 Plant growth characteristics

The application of NPK (100 g/ seedling) and NPK 50 g + PM 400 g significantly ($p<0.05$) produced taller plants compared to control at Bole while at Nkonsia the PM (400 g/seedling) treatment significantly ($p<0.05$) gave taller plants compared to sole NPK (50 g/seedling) and control (Table 3). The higher N content in the NPK (100 g/seedling) treatment ensured the rapid release of nutrients especially N for plant growth. Again, the low N content of the soil at Bole responded very well to the applied N in the NPK (100 g/seedling) thereby leading to the taller plants produced by that treatment. Among the treatments, soils amended with PM (T3) at Nkonsia and PM + NPK (T6) at Bole had a higher proportion of vigorous plants, indicating a probable adequate nutrient availability due to PM and high soil moisture due to improved moisture holding capacity by the PM to ensure their survival. On the other hand, the treatment that had no amendment (T7) had the least proportion of vigorous plants (Table 3). The generally less vigorous growth in the unfertilized control plots may be due to the nutrient deficiency effect (Acheampong et al., 2015). Conversely, more vigorous trees have a higher survival rate than less vigorous plants under drought stress conditions (Hutcheon, 1973).

The slightly acidic nature of the soils, low OC, and N, in baseline soil (Table 2) suggests that the poor growth of these cashew seedlings in T7 was as a result of low availability and/or uptake of N and that this deficiency was exacerbated by lack of nutrient supply from an external source through fertilizer applications. Although OC, N and P were in the critically low range at the experimental site, the application of PM alone at Nkonsia (T3) and its combination with NPK (T6) at Bole improved growth. The PM amendments had a considerable role in the provision of these nutrients, either by direct decomposition of the PM or by influencing their availability through critical roles such as mineralization of organic matter. The rapid growth response of cashew seedlings to the PM amendments in this experiment suggests that PM stimulated processes in the labile OC pool (Woomer et al., 1994), resulting in increased availability of nutrients, particularly macronutrients. The low C:N ratio (9.0) of the PM used for the entire duration of the study (Table 1) promoted rapid decomposition and release of nutrients from the added PM. Soil microbial populations and activity play a crucial role in nutrient availability; therefore, the addition of PM (Burger and Jackson, 2003) may have boosted their activity for the release of nutrients into the soil. Additionally, a high proportion of soil N, particularly in weathered tropical soils like the soil used for the study, occurs in organic matter (Steiner et al., 2007) and it was obvious that the PM amendments either alone or in combination with NPK enhanced the availability of N, enabling vigorous growth.

Table 3: Effects of different soil amendments on plant growth parameters

Treatments	Bole			Nkonsia		
	Height (cm)	Girth (mm)	Vigour	Height (cm)	Girth (mm)	Vigour
T1 NPK 50g	241.0^{ab}	76.7a	3.1^{ab}	171.4^{a}	67.7^{a}	2.6^{a}
T2 NPK 100 g	263.3^{b}	86.6^{a}	3.1^{ab}	202.7^{ab}	70.1^{a}	2.9^{abc}
T3 PM 400 g	251.4^{ab}	80.9^{a}	3.1^{ab}	231.6^{b}	71.3^{a}	3.3^{c}
T4 PM 800 g	227.0^{ab}	84.4^{a}	2.7^{ab}	211.2^{ab}	76.6^{a}	2.7^{ab}
T5 NPK 25 g + PM 200 g	239.1^{ab}	84.3^{a}	2.9^{ab}	189.4^{ab}	67.3^{a}	2.8^{abc}
T6 NPK 50 g + PM 400 g	262.6^{b}	77.2^{a}	3.4^{b}	214.1^{ab}	69.6^{a}	3.1^{bc}
T7 Control (unfertilized)	217.6^{a}	74.9^{a}	2.9^{ab}	176.9^{a}	65.7^{a}	2.7^{ab}
SED (df) = 12)	17.4	6.6	0.3	20.8	7.3	0.2

PM = poultry manure; Means in a column followed by the same letters are not significantly different at $p < 0.05$.

4. Conclusion and Recommendation

This study has demonstrated that the sole application of organic manure or combined use of organic and inorganic fertilizers on less fertile soils will greatly benefit the nutrition of cashew plants. Despite increasing the readily available N with NPK at Bole, sole application of NPK did not produce the highest vigorous plants as the treatment that was amended with sole PM (400 g) at Nkonsia. Organic matter played a role in promoting the uptake of nutrients, resulting in generally higher plant vigour and highly improved vigour of cashew plants in treatments with PM amendments. The possibility and benefit of supplying nutrients to cashew plants by combining PM (organic fertilizer) and NPK (inorganic fertilizer) have been clearly shown in this study. The best growth and vigour were recorded for T6 (NPK 50 g + PM 400 g) at Bole and T3 (PM 400 g/seedling) at Nkonsia. From their preeminence over the other treatments in promoting growth, they would ensure improved establishment success and more vigorous growth of cashew plants in less fertile soils.

Acknowledgments

The authors are grateful for the immense technical support of the staff of the Soil Science Division and Bole Substation of the Cocoa Research Institute of Ghana in carrying out this research

References

Abbasi, M. K., Hussain, F., Majid, S. A. (2002). Changes in the behaviour and physical and chemical characteristics of soil after adding Populuseur americana leaves. Sci. Tech. Develop. 21, 15–19.

Acheampong, K. Hadley, P. Daymond, A and Adu -Yeboah, P. (2015). The influence of shade and organic fertilizer treatments on the physiology and establishment of Theobroma cacao clones," American Journal of Experimental Agriculture, 6 (6):347–360.

Agbede, T. M and Adekiya, A. O. (2016). Effect of cocoa pod ash and poultry manure on soil properties and cocoyam productivity of nutrient-depleted tropical Alfisol. International Journal of Agricultural and Biosystems Engineering, 10 (3): 172-179.

Agyenim Boateng, S., Zickermann, J. and Kornahrens, M. (2006). Poultry Manure Effect on Growth and Yield of Maize. West Africa Journal of Applied Ecology, (9): 1-11.

Akoun, J. (2004). Effect of plant density and manure on the yield and yield components of the common onion (Allium cepa L.) var. nsukka red. Nigerian Journal of Horticultural Science, 9: 43-48.

AOAC, Official Methods, Association of Official Analytical Chemists, Washington, DC, 12th edition, 1990.

Ayeni, L. S., E. Omole, M. T. Adetunji and S. O. Ojeniyi. (2009). Integrated application of NPK fertilizer, cocoa pod ash and poultry manure: effect on maize performance, plant and soil nutrient content. International Journal of Pure and Applied Sciences. 2 (2):34-41.

Bhaskar, B., Salam, M.A and Wahid, P.A. (1995). Nutrient offtake in cashew. Cashew, 9: 9-16

Bibi, Z., N. U. Khan, M. Akram, Q. U. Khan, M. J. Khan, S. Batool and K, Makhdoom (2010). Maize response to integrated use of NP-fertilizers and compost. Pak. J. Bot., 42: 2793-2801.

Bokhtiar, S. M. and Sakurai, K. (2005). Effects of organic manure and chemical fertilizer on soil fertility and productivity of plant and ratoon crops of sugarcane. Archives of Agronomy and Soil Science. 51: 325 - 334.

Burger, M. and Jackson, L. E. (2003). Microbial immobilization of ammonium and nitrate in relation to ammonification and nitrification rates in organic and conventional cropping systems, Soil Biology and Biochemistry, 35 (1):29–36.

Dauda, S. N., Ajayi, F. A. and Ndor, E. (2008). Growth and yield of water melon (Citrullus lanatus) as affected by poultry manure application. Journal of Agriculture and Social Science, 4: 121-124.

Dedzoe, C. D., Seneyah, J. K. and Asiamah, R. D. (2001). Suitable Agro-ecologies for cashew (Anacadium occidentale L.) production in Ghana. West African Journal of Applied Ecology, 2:103-115.

Dogbatse, J. A., Arthur, A. Awudzi, G. K. Quaye, A. K. Konlan, S. and Amaning, A. A. (2021). Effects of Organic and Inorganic Fertilizers on Growth and Nutrient Uptake by Young Cacao (Theobroma cacao L.). International Journal of Agronomy.

Dutta, S., Pal, R. Chakeraborty, A. and K. Chakrabarti, K. (2003). Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil. Archives of Agron. and Soil Sci., 49: 631-637.

Ewulo, B. S., O. O. Babadele and S. O. Ojeniyi. (2009). Sawdust Ash and Urea Effect on Soil and Plant Nutrient Content and Yield of Tomato: Am.-Eurasian J. Sustain. Agric. 3(1):88-92.

Ghosh, S. N. (1989). Effect of nitrogen, phosphorus and potassium on flowering duration, yield and shelling percentage of cashew (Anacardium occidentale L.) Indian Cashew Journal 19:19-23.

Grundon, N. J. (1999). Cashew nuts in North Queensland respond to phosphorus and sulfur fertilizers.
Better Crops International 13:22-24.

Hutcheon, W. V. (1973). Breeding for tolerance of exposure and the ability to respond to increased radiation, pp. 203-204, Cocoa Research Institute of Ghana, Ghana.

Khan, M. S., Shil, N.C and Noor, S. (2008). Integrated nutrient management for sustainable yield of major vegetable crops in Bangladesh. Bangladesh J. Agric Environ 4: 81-94.

Kotschi, J. (2013). A soiled reputation: Adverse impacts of mineral fertilizers in tropical agriculture. Heinrich Boll Foundation and WWF, Berlin, Germany, May 22, 2013.

Macit, I., Koc, A. Guler, S.and Deligoz, I. (2007). Yield, quality and nutritional status of organically and conventionally-grown strawberry cultivars. Asian J. Plant Sci. 6(7):1131-6.

Mitchell C. C. and Donald J. O. (1995). The value and use of poultry manures as fertilizer. Circular ANR – 244, Alabama, A & M and Auburn universities. 3 pp.

Ogunwale, J. A., J. O. Olaniyan and M. O. Aduloju. (2002). Morphological, physio-chemical; and clay mineralogical properties of soils overlaying basement complex rocks in Ilorin East, Nigeria. Moor Journal of Agricultural Research, 3.2: 147-154.

Onasanya, O. P., Aiyelari, A., Onasanya, S., Oikeh, F. E., Nwilene, O. (2009). Growth and yield response of Maize (Zea mays L.) to different rates of Nitrogen and Phosphorus fertilizers in Southern Nigeria. World J. Agric. Sci. 5(4):400-407, 2009.

Palm, C. A., Gachengo, C. N., Delve, R. J., Cadisch, G., Giller, K. E. (2001). Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. Agric. Ecosys. Environ. 83, 27–42.

Soumare, M., Tack, F. M. G., Verloo, M. G. (2003). Effects of a municipal solid waste compost and mineral fertilization on plant growth in two tropical agricultural soils of Mali. Bioresour. Tech. 86: 15–20.

Sparks, D. L., A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A. Tabatabai, and C. T. Johnston. 1996. "Methods of Soil Analysis, Part 3." SSSA Book series No. 5. Madison, USA: Soil Science Society of America and America Society of Agronomy.

Steiner, C., Teixeira, W. G. and Lehmann, J. (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil, Plant and Soil, 291 (1-2): 275–290.

Tollesa, D. (1999). Effect of organic and inorganic fertilizers on maize grain yield in western Ethiopia. African Crop Science Conference Proceedings, 4: 229-232.

Woomer, P. L., Martin, A. Albrecht, A. Resck, D. V. S. and Scharpenseel, H.W. (1994). The importance and management of soil organic matter in the tropics, in The Biological Management of Tropical Soil Fertility, P. L. Woomer and M. J. Swift, Eds., pp. 47–80, Wiley-Sayce Publications, Chichester, UK, 1994.

Yaduvanshi, N. P. S. (2003). Substitution of inorganic fertilizers by organic manures and the effect on soil fertility in rice–wheat rotation on reclaimed sodic soil in India. J. Agric. Sci. 140, 161–168.

YIELD ENHANCEMENT OF CASHEW (*ANACARDIUM OCCIDENTALE*) NUT THROUGH APPROPRAITE FERTILIZER APPLICATION IN IBADAN, NIGERIA

***C.I. Iloyanomon., O.S. Ibiremo, and M.O. Ogunlade,**

Cocoa Research Institute of Nigeria, P.M.B. 5244, Ibadan, Nigeria.

*Corresponding author iloya2000@yahoo.com

Abstract

Cashew nut is an important source of foreign exchange earnings; however, its yield is limited by soil nutrient deficiency. Field experiment was conducted in Ibadan, rainforest agro-ecological zone of Nigeria to examine the influence of various fertilizer types on yield of cashew nut. Treatments applied were inorganic fertilizers (NPK 20:10:10), organic fertilizer (market and abattoir waste compost), organomineral fertilizer, no-fertilizer unpruned and no-fertilizer pruned. All treatments were arranged in a randomized complete block design with four replications. Fertilizers were applied based on soil test to supply 20 Kg N/ ha. All the cashew trees were pruned except, the no-fertilizer unpruned treatment. Data was collected on number and weight of cashew nuts. Results indicated that organic fertilizer significantly ($P<0.05$) enhanced number of cashew nuts (231 nuts/tree) when compared to no-fertilizerpruned (100 nuts/ tree), no-fertilizer unpruned (85 nuts/tree) and inorganic fertilizer (153 nuts/tree) with increases of 53 – 172 %. Organomineral and organic fertilizer treatments had similar number of nuts. All fertilizer treatments also significantly ($P<0.05$) enhanced cashew nut weight (1.39 – 1.82 kg/tree) when compared with no-fertilizer pruned (0.95 kg/tree) and no-fertilizer unpruned (0.84 kg/tree) with an increase of 46 – 117 %. Organomineral fertilizer resulted in heavier cashew nuts (1.82 kg/tree) when compared with inorganic fertilizers (1.53 kg/tree) and organic fertilizer (1.39 kg/tree) with an increase of 19 % and 31 % respectively. Fertilizers irrespective of formulation increased cashew nut yield in Ibadan.

Keywords: Fertilizer type, cashew nut yield, soil critical level

1. Introduction

Cashew (*Anacardium occidentale*) is an important commodity crop grown in a wide range of agro-ecological zones. It is a hardy crop which is perceived to be less demanding in terms of soil type and fertility requirement when compared with many plantation crops. Cashew is therefore tagged a "low input crop" and it is grown on poor soils where other tree crops cannot grow. This has affected cashew productivity, thus creating a need for nutrient supplementation as fertilizer. Fertilizer is not commonly used in cashew production system in Nigeria. This has made cashew productivity largely dependent on natural soil endowment and cashew litter. Consequently, the soils upon which cashew are cultivated are maintained through litter fall and other natural endowment. This has adversely affected cashew yield. Cashew generates 9.65 - 10.98 tons/ha of leaf litter (Iloyanomon and Taiwo, 2017). However, the nutrient in cashew litter is insufficient to meet the nutrient need of the tree (Iloyanomon and Taiwo, 2017). The application of fertilizer is therefore inevitable to replacement of soil nutrients mined through cashew apple and nut harvest. Cashew has been shown to benefit from fertilizer application with resultant increase in cashew nut yield (Gavit, 2017; Iloyanomon et al., 2019). There is therefore the need to investigate the influence of fertilizer application on yield of cashew nuts in Ibadan.

2. Methodology

The study which was carried out in Cocoa Research Institute of Nigeria (CRIN), Ibadan, Oyo state is located in the forest ecological zone of Nigeria. The climate is humid tropic with two seasons per year. A wet season from March to October or early November with two weeks dry spell in August. The dry season runs from November to March. The dry season is characterized by scorching sun and dry atmosphere, with scanty rain. Maximum temperature in Ibadan ranges between 26°C to 35°C with an average daily temperature of 30°C. Relative humidity is high all year round but higher in the rainy season with a range of 60 % - 85 % during the wet season and 46 % to 60 % during the dry season.

Fertilizer was applied based on soil test result to supply 20 Kg N/ ha. The treatments were:

a. No-fertilizer pruned

b. No-fertilizer unpruned

c. Inorganic fertilizers (NPK 20:10:10)

d. Organic fertilizer (1.2 % N, 1.08 % P, 1.78 % K, 1.98 % Ca, 0.09 % Mg) Market and abattoir waste compost.

e. Organomineral fertilizer

The treatments were arranged in a randomized complete block design (RCBD) with four replications. Each treatment was applied to six cashew trees per replication giving a total of 120 trees. The cashew trees were spaced at 9 m x 9 m and were pruned except, the no-fertilizer unpruned treatment. Data was collected on number and weight of cashew nuts of the various experimental units. Data collected were subjected to statistical analysis and significant means separated using Duncan multiple range test at 5 % level of probability.

Prior to establishment of the experiment, soil auger was used to collect soil sample from the cashew plantation at 0-20 cm and 20-40 cm soil depth. The soil samples collected were air dried, passed through 2 mm sieve and analyzed in the laboratory for some of its physical and chemical properties. Particle size analysis was determined using hydrometer method as described by Bouyoucos (1951). Soil pH determined in soil to water ratio (1:1) using a digital pH meter as described by Jackson (1965). Organic carbon was determined by Walkey and Black procedure as described by Nelson and Sommer (1982). Total nitrogen was determined by Kjeldahl method (IITA, 1982), while available phosphorus was determined by Bray- P-1 method (Bray and Kurtz, 1945). Exchangeable bases (potassium, calcium, magnesium, and sodium) were extracted with 1N neutral ammonium acetate (NH4OAC). The amount of potassium and sodium in the filtrate were determined using flame photometer, while calcium and magnesium were determined using a Perkin-Elmer Atomic Absorption Spectrophotometer (AAS).

Leaf samples were also collected from the cashew trees. The leaves collected were oven dried to constant weight, milled and total nitrogen, phosphorus, potassium, calcium, magnesium, iron, copper, manganese and zinc nutrient content of the leaves analysed.

3. Results and Discussion

Soils in cashew plantation was neutral with pH values ranging between 6.99 and 6.90 at 0 - 20 cm and 20 - 40 cm soil depth respectively (Table 1).

Table 1: Initial physical and chemical properties of soils of cashew plantation in Ibadan, Nigeria

PARAMETERS	Soil depth (cm)	
	0 - 20	20 - 40
pH	6.99	6.99
Organic carbon (g/kg)	10.30	5.20
N (g/kg)	0.80	0.60
P (cmol/kg)	7.73	5.33
K (cmol/kg)	0.24	0.17
Ca (cmol/kg)	12.48	9.94
Mg (cmol/kg)	1.31	0.92
Na (cmol/kg)	0.52	0.37
Ex base (cmol/kg)	14.55	11.40
Ex. Acidity (cmol/kg)	0.06	0.07
ECEC (cmol/kg)	14.61	11.47
Base saturation (%)	99.59	99.39
Zn (mg/kg)	7.52	5.20
Cu (mg/kg)	1.40	1.59
Mn (mg/kg)	18.70	12.16
Fe (mg/kg)	8.45	18.05
Sand (g/kg)	758	800
Silt (g/kg)	194	156
Clay (g/kg)	48	44
Textural class	Loamy sand	Loamy sand

Soil organic carbon and was low and decreased with increasing soil depth with values of 10.30 and 5.20 g/kg at 0 - 20 cm and 20-40 cm soil depth respectively. Similarly, total soil nitrogen decreased with increasing soil depth with values of 0.8 g/kg and 0.6 g/kg at 0-20 cm and 20- 40 cm soil depth. This nitrogen value was below the soil critical level of 1 g/kg nitrogen required for cashew (Egbe et al., 1989), hence inadequate for cashew production. There was therefore the need for nitrogen fertilizer. This was corroborated by the leaf nitrogen content of 11.8 g/kg (Table 2), which were below the foliar critical N value of 12.4 g/kg required by cashew.

Table 2: Initial leaf nutrient content of cashew plantation in Ibadan, Nigeria

Nutrient content	g/kg)
Nitrogen	11.8
Phosphorus	1.03
potassium	8.37
Calcium	15.2
Sodium	3.7
Magnesium	4.5
Zinc	0.07
manganese	0.18
Iron	0.23
Copper	0.08

Soil available phosphorus was adequate with values of 7.73 mg/kg and 5.33 mg/kg at 0-20 cm and 20 – 40 cm soil depth (Table 1). This was well above the soil critical phosphorus value of 3.7 mg/kg required for cashew (Egbe et al., 1989). There was therefore no need for phosphorus fertilizer. Similar trend was observed were soil exchangeable potassium at the top 0-20 cm soil depth (0.24 cmol/kg) was adequate (Table 1), making potassium fertilization unnecessary. High calcium (12.48 cmol/kg) and magnesium content (1.31 cmol/kg) was also observed at 0 -20 cm soil depth (Table 1). This is above the soil critical value of 8 cmol/kg and 0.08 cmol/kg of calcium and magnesium respectively required for cashew. There was therefore no need for calcium and magnesium fertilization. This was corroborated by the high leaf calcium content of 15.2 g/kg and magnesium content of 4.5 cmol/kg (Table 2). This was well above the foliar critical level of 1.8 g/kg calcium and 8.8 g/kg magnesium required for cashew. This high calcium and magnesium content were responsible for the neutral pH value of the soil. Zinc content of the soil was also high while, iron, copper and manganese were sufficient in the soil (Table 1).

All fertilizer treatments increased the number of cashew nuts significantly ($P<0.05$) (Table 3). Organic fertilizer (231 nuts/tree) increased number of cashew nuts when compared to no-fertilizer pruned (100 nuts/ tree), no-fertilizer unpruned (85 nuts/tree) and inorganic fertilizer (153 nuts/tree) with increases of 131 %, 172 % and 51 % respectively (Table 3). Organomineral fertilizer (194 nuts/tree) also resulted in higher number of cashew nuts when compared with no-fertilizer pruned and no-fertilizer unpruned with increases of 94 % and 128 % respectively. Similarly, inorganic fertilizer resulted in 53 % and 80 % higher number of cashew nuts when compared with no-fertilizer pruned and no-fertilizer unpruned. Organomineral and organic fertilizer treatments had similar number of nuts. Similar observation was made by Iloyanomon et al. (2019) in Ochaja, Kogi state where inorganic and organomineral fertilizers increased number of cashew nuts by 303 % and 154 % respectively when compared with no fertilizer application.

Table 3: Number and weight (kg) of cashew nuts per tree as influenced by

fertilizer types at Ibadan, Nigeria

Treatments	Number of nuts/tree	Weight of nuts/tree(kg)
No fertilizer pruned	100c	0.95c
No fertilizer unpruned	85c	0.84c
Inorganic fertilizer	153b	1.53b
Organic fertilizer	231a	1.39b
Organomineral fertilizer	194ab	1.82a
SE±	125.11	0.25

Means with the same letter(s) within the same column are not significantly different at $P<0.05$ using Duncan multiple range test (DMRT)

Abbreviation

SE± Standard error

Fertilizer treatments also influenced weight of cashew nuts significantly ($P<0.05$) (Table 3). All fertilizers irrespective of formulation (1.39 – 1.82 kg/tree) increased cashew weight when compared with no-fertilizer pruned (0.95 kg/tree) and no-fertilizer unpruned (0.84 kg/tree) with an increase of 46 – 117 %. Organomineral fertilizer (1.82 kg/tree) also resulted in heavier cashew nut when compared with inorganic fertilizers (1.53 kg/tree) and organic fertilizer (1.39 kg/tree) with an increase of 19 % and 31 % respectively. Inorganic and organic fertilizers produced similar cashew nut weight. This is consistent with findings of Rupa and Kalaivanan (2014) who reported 53.1% and 48.4 % increase in cashew nut yield on application of NPK + Farm yard manure. The different fertilizer types increased cashew yield by increasing both the number of nuts and size of nuts.

The positive response of cashew nut yield to the fertilizers could be attributed to the low nutrient status of the soil which indicated a need for nitrogen. The quick mineralization of these fertilizers led to the release of these needed nutrients, making them readily available to increase cashew nut yield. Organomineral fertilizer performed better than either organic or inorganic fertilizer in terms of weight of cashew nut. Similar findings were reported by Zingore et al. (2008) and Vanlauwe et al. (2010). This is because organomineral fertilizer combines the benefit of both organic and in organic fertilizers, hence the superior result in terms of balanced plant nutrient and improved soil fertility (Brar, 2015). Pruning of cashew trees without fertilizer application had no influence on number and weight of cashew nuts (Table 3). This indicated that pruning alone without appropriate fertilizer application was not beneficial. This is pruning alone can not substitute for fertilizer application.

Conclusion

Organic, inorganic and organomineral fertilizers increased cashew nut yield by increasing number and weight of cashew nuts by 53 – 172 % and 46 -117 % respectively. Pruning of cashew trees without fertilizer application was not beneficial. The use of fertilizer is therefore beneficial in enhancing cashew productivity.

Acknowledgement

The authors are grateful to Dr. P. Adebola, the Executive Director/Chief Executive Officer of Cocoa Research Institute of Nigeria for providing funds and the necessary facilities during the course of this investigation.

References

Bouyoucos , G. J. (1951). Hydrometer methods improved for making particle size analysis of soils. Agronomy Journal 54, 465.

Brar, B.S., Singh, J., Singh, G., & Kaur, G. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. Agronomy (5),220-238.

Bray, R.H., & Kurtz, L.T. (1945). Determination of total organic and available forms of phosphorus in soils. Soil Science 59 (1), 39-46.

Egbe, N.E., Ayodele, E.A., & Obatolu, C.R. (1989). Soils and nutrition of cocoa, coffee, kola, cashew, and tea. In: Progress in the Crop Research in Nigeria (2nd Edition), CRIN Ibadan.

Gavit, S.J. (2017). Effect of different levels of nitrogen, phosphorus, potassium along with soil and foliar application of zinc and boron on yield and quality of cashew nut (Anacardium occidentale L) in lateritic soil of Konkan. Ph.D thesis submitted to Dr. Balasaheb Sawani Konkan Krishi Vidyapeeh, Dapoli Agricultural university Dist. Ratnagira Maharashtra state, India 259PP.

IITA (International Institute of Tropical Agriculture) (1982). Automated and semi-automated methods for soil and plant analysis. Manual series 7. International Institute of Tropical Agriculture, Nigeria pp 33.

Iloyanomon, C.I., & Taiwo, N. (2017). Contribution of leaf litter to natural soil fertility management of cashew plantations of different ages. Proceedings of the 35th Annual conference of the Horticultural Society of Nigeria. PP 490-493.

Iloyanomon C.I. Ibiremo., O.S., & Ogunlade, M.O. (2019). Influence of appropriate fertilizer application on yield of cashew (Anacardiun occidentale) in Ochaja, Kogi state. Proceeding of the 37th Annual conference of the Horticultural Society of Nigeria held at Rufus Giwa Polytechnic, Owo, Ondo state. 18th - 22nd November, PP. 392 – 395.

Jackson, M.L. (1965). Methods of soil analysis. A.S. monogram. 9,45.

Nelson, D. W., & Sommers, L.E. (1982). Total carbon, organic carbon, and organic matter. Methods of soil analysis part 2 chemical and microbiological properties. A. L. Page Ed. American Society of Agronomy, Soil Science Society of America, Madison WI: Agronomy Monogram (9.2),539-579.

Rupa, T.R., & Kalaivanan, D. (2014). Integrated nutrient management in cashew for increased production with increased sustainability. International symposium on plantation crop 10 – 12 December 2014.

Vanlauwe, B., Bationo, A., Chianu, J., Giller, K.E., Merckx, R., Mokwunye, U., Ohiokpehai, O., Pypers, P., Tabo, R., & Shepherd, K. (2010). Integrated soil fertility management: operational definition and consequences for implementation and dissemination. Outlook 0n Agriculture (39),17–22.

Zingore, S., Murwira, H.K., Delve, R.J., & Giller, K.E. (2008). Variable grain legumes yield, response to phosphorus and rotational effects on maize across soil fertility gradients on African smallholder farms. Nutrient Cycling Agroecosystem (80),1–18.

.

PERFORMANCE OF 26 SELECTED ELITE CASHEW HYBRIDS DEVELOPED IN 1996 UNDER THE ENVIRONMENTAL CONDITIONS OF CHAMBEZI-BAGAMOYO, THE EASTERN PART OF TANZANIA

Dadili J. Majune[1*], Joachim P. Madeni[1], Zabron S. Ngamba[1], Geradina P. Mzena[1], Fortunus A. Kapinga1 and Peter A. Masawe[2]

[1]Tanzania Agricultural Research Institute, TARI-Naliendele, 10 Newala Road P.O. Box 509 Mtwara, Tanzania
[2]International cashew value chain specialist
*E-mail of corresponding author: dmajune@yahoo.com/dadilimajune75@gmail.com

Abstract

Cashew (Anacardium occidentale L.) is a crop of economic importance in terms of foreign exchange earnings and income generation for the household for tropical countries including Tanzania. However, its productivity is facing a number of challenges and among them are low yielding planting materials, poor nut quality and susceptibility to major disease and insect pests. Efforts to address the problems are being implemented by cashew breeders in Tanzania. One of the methods of increasing genetic variation for future selection is by crossing selected parents for the development of superior cultivars. In 1996, cashew breeding section developed 284 new hybrids through hand pollination using high yielding and desirable nut quality parameters. The hybrids were planted and data were recorded on individual tree basis for seven years and thereafter 26 elite hybrids were selected for advanced trial. The results showed significant differences ($P \leq 0.001$) among the hybrids for all characters studied. The trial means for yield, nut weight, kernel weight and % outturn (OT) were 19.76 kg, 8.11g, 2.35 g and 29.29% respectively at the age of ten years. The mean performance for yield, nut quality and vegetative characters of cashew hybrids at Chambezi was assessed and the hybrid C15-2-2 had the highest yield (40.21 kg/tree) which was not significantly different ($P \leq 0.001$) from hybrid C19-4 (35.7 kg/tree). The third hybrid was attained by C13-1 (25.89 kg) which was not statistically significant different from 19 other hybrids. On nut quality assessment, hybrid C9-3 was leading by attaining (10.6 g) high nut weight and was not significantly different from other two hybrids C4-1 (10.32 g) and C7-2 (9.98 g). Kernel weight was attained by hybrid C9-3 and %OT was attained by hybrid C19-4 and was within the range required. These hybrids have demonstrated an outstanding performance in yield and nut quality. Therefore, they are recommended for inclusion in the list of improved planting materials and its multiplication and distribution in Chambezi and areas which have similar environmental conditions.

Key words: *Cashew, hybrids, percentage outturn, high yielding, cashew nut quality*

1.0 Introduction

Cashew (Anacardium occidental L.) is a tree crop is of high economic importance at both household and national levels. However, the biggest problem in cashew production is lack of improved cashew planting materials (Mole, 2000 & Dendena & Corsi, 2014). This is because the majority of cashew trees in farmers' fields have been raised from unimproved materials. These cashew trees are low yielding with variable nut sizes, low kernel weight, low percentage kernel outturn. They are also susceptible to insect pest and diseases (Dadzie et al. 2014 & Masawe and Kapinga 2017). So improving productivity is a challenge that needs attention in cashew industry worldwide. The development of improved cashew planting materials which are resistance to biotic and abiotic factors is one of the approaches towards increasing productivity of the cashew crop. However the concept of cashew hybridization remains to be a driving force in cashew improvement programmes. Hybridization is labour intensive and time consuming due to the fact that the whole process starts from hand pollination to nut harvesting which takes three to four months (Masawe, 2009). Hybridization of seed usually requires field evaluation period of not less than six years before mass selection is taking place. The selected elite hybrids need to undertake field evaluation in replicated trials and different agro ecological zones. The field trials will prove that the performance of hybrids developed is genetically or environmentally controlled (Masawe, 2009).

Evaluation of hybrids produced in 1996/1997 was carried out at Tanzania Agricultural Research Institute (TARI), Naliendele in Mtwara region from 2001 to 2007, from which 26 elite hybrids were selected for further evaluation in advanced trial. The selection of these elite hybrids was based on nut yields, nut size, kernel weight, percentage outturn and resistance to insect pests and diseases. However the performance of these elite hybrids was based on data from a single site. It was important to test them in contrasting environment to find out if their performance was due to favourable environment condition or genetic trait (Masawe, 2009). Hence, the field trial for evaluation of the elite hybrids was set at Chambezi-Bagamoyo in the eastern part of Tanzania. As similar to genetic trials, hybridization by hand pollination was initiated and the first cashew hybrids were developed in Tanzania in 1991 (Masawe, 1994). Evaluation of these hybrids was carried out for 10 years at Naliendele Agricultural Research Institute from 1992 to 2002, from which 26 elite hybrids were selected for further evaluation in an advanced cashew trial. The objective of this trial was to find out if the selected hybrids would perform well in terms of yield and nut quality attributes under condition of Chambezi, Bagamoyo.

2.0 Materials and methods

The study was conducted in two independent sites. The hybrids were developed as hand pollinated cashew nuts seeds which were planted at TARI Naliendele located at 10.38°S, 38.77°E; 393 metres above sea level in Mtwara region in southern part of Tanzania and 26 selected elite hybrids were planted at Chambezi-Bagamoyo (6°31'S and 38°55'E; 19 m above sea level) which is located in Eastern part of Tanzania using grafted seedlings. Bagamoyo District lies between 370 and 390 Longitude and between 600 and 700 Latitude (District Profile, 2006, 2009). The district has seasonal average temperatures ranging from 13°C to 30°C and humidity as high as 98 % (EPMS, 2006). Rainfall ranges between 800 and 1200 mm per annum. The short rains season starts from October to December while the long rains season starts from March to May (District Profile, 2006; Andrew, 2009; Mushi, 2009). The driest months are June to September when monthly rainfall is generally less than 50 mm per month. Dominant soil types include sand, loam, sandy-loam and clay (District profile, 2006).

Twenty six (26) high yielding elite cashew hybrids with good nut quality were selected from hybrids developed by hand-pollination that was done in year 1996. These selected elite hybrids were vegetatively propagated at Tanzania Agricultural Research Institute (TARI) Naliendele nursery in October 2009. Grafted seedlings were transported to Chambezi research substation in Bagamoyo (Coast Region) for trial establishment in March 2020. A high yielding cashew variety (AC4) was used as control bringing the total number of entries to 27. The list of selected cashew hybrids and their performance during selection are shown in Table 1. The trial was laid out in a randomized complete block design with three replication at 12 m x 12 m spacing. There were four trees per plots. Formative pruning was carried out to form the desirable umbrella shaped tree canopy to enable easy nut collection underneath the cashew trees as well as to allow tractor and other machinery to operate in the farm during weeding. Gap filling was undertaken in the second year to maintain optimum plant population. Powdery mildew disease was controlled using a water-based fungicide (Triadimenol) at a rate of 10-15 mls/litre (spayed three times at an interval of 21 days). Insect pests were controlled using insecticide Lambada cynhalothrin at a rate of 3-5 mls/litre applied when symptoms of attack were noted (Majune et al, 2018; Sijaona et al. 2009). The yield and nut quality were recorded on a tree basis for eight years from 2011 to 2018. Data analysis was carried out using GenStat statistical software (GenStat Discovery Edition 16). Duncan's Multiple Range Test was used to separate the means.

Table 1: Parents crossed for the elite hybrids developed in 1996 for evaluation at Chambezi-Bagamoyo

Serial	Crossed Parents (Female x Male)	=	Hybrid
1	AC28/94 x ATRIN		C3-1
2	AC6/445 x BRZ11.21		C15-2
3	AC6/445 x BRZ11.21		C15-3
4	AC4 x BRZ10.16		C14-4
5	AC28 x BRZ10.16		C5-2
6	AC4/17 x BRZ4.4		C7-1
7	AC4/17 x BRZ4.4		C7-2
8	AC6/445 x BRZ11.21		C15-2
9	AC6/445 x BRZ11.21		C15-4
10	AZA2/339 x BRZ10.16		C22-4
11	AC/263 x ATRIN		C10-4
12	AC4 x AJ74		C13-2
13	AC4/17 x BRZ4.4		C7-1
14	AC4/263 x ATRIN		C10-1
15	AC4/263 x ATRIN1		C10-4
16	AC1/75 x AJ74		C1-2
17	AC1/75 x AJ74		C1-3
18	AC1/75 x AJ74		C1-4
19	AC28 x BRZ10.16		C5-1
20	AC6 x BRZ11.21		C19-4
21	AC4/259 x BRZ4.4		C9-3
22	AC4 X AJ74		C13-1
23	AC4 X AJ74		C13-4
24	AC28 x BRZ10.16		C4-1
25	NTP88/04 x BRZ4.4		C25-3
26	AC6/445 x BRZ11.21		C15-2
27	AC4 (control)		C-C

3.0 Results

The results indicated that there were highly significant differences in performance of all parameters measured ($P \leq 0.01$) from 2012 to 2018 (Table 2). The trial means for nut yields, nut weight, kernel weight and %OT recorded were 19.76 kg, 8.11 kg, 2.35 kg and 29.29 kg respectively. The trial mean yield was increasing when cashew trees were three years old and continued to increase. The coefficient of variations for data recorded on nut yield, nut weight, kernel weight and %OT were 33.50%, 15.40%, 16.10% and 10.30% respectively are relatively low and within the range.

Table 2. Summary analysis of variance for yield, nut weight, kernel weight and percentage outturn of 26 selected elite hybrids developed in 1996 at Chambezi Bagamoyo.

Source	df	Means									
		Y2012	Y2013	Y2014	Y2015	Y2016	Y2017	Y2018	NutWt (g)	KernWt (g)	%OT (%)
Rep	2	152.52**	231.56**	17.44*	703.08**	770.92**	622.04**	331.01*	5.14**	0.18	33.67**
Hybrid	26	53.007**	62.59**	44.986**	118.15**	137.72**	216.82**	513.3**	16.10**	0.95**	41.21**
Error		7.34	10.81	5.93	26.27	36.64	33.48	111.50	1.56	0.14	9.13
Mean		3.82	5.68	8.08	11.84	12.70	17.34	19.76	8.11	2.35	29.29
CV(%)		46.50	44.90	41.40	39.90	37.60	43.40	33.50	15.40	16.10	10.30

**P ≤0.01; ***P ≤0.001; NutWt = Nut weight; KernWt = Kernel weight; %OT = Percentage outturn

The Duncan's Multiple Range Test was used for means separations. Results on nut yields, nut weight, kernel weight %OT are presented in Table 3. The data showed that the highest yielding elite hybrids was C15-2-2 with nut yield of 40.21 kg/tree and it was not statistically significant different from the second hybrids C19-4 (35.7 kg/tree). The third hybrids was attained by elite hybrid C13-1 (25.89 kg/tree) which was statistically significantly different from the second elite hybrids but was not statistically significantly different from other nineteen elite hybrids. The control variety AC4 which is the reading clone in Tanzania was ranked the tenth among the elite hybrids selected. Hybrid C9-3 was the lowest yielder compared to other elite hybrids examined items of yield.

By considering the nut weight, elite hybrid C9-3 (10.6 g) had the highest nut weight which did not differ significantly from other two elite hybrids C4-1 (10.32 g) and C7-2 (9.99 g). The control variety AC4 scored the 13th in nut size when compared with other elite hybrids and the lowest hybrid with nut size was C19-4. The highest kernel outturn was attained by elite hybrid C9-3 (3.06 g) and it was statistically significant different from other hybrids. However the second hybrid was excelled by elite hybrid C7-1-6 (2.73 g) and was not statistically significant different from other eleven elite hybrids. The lowest kernel weight recorded was hybrid C19-4 which was not statistically significant different from hybrid C15-3. However by considering the percentage kernel outturn the elite hybrid C19-4 (32.4%) was the reading but was not statistically significant different from other fifteen elite hybrids and the lowest percentage kernel outturn was attained by C4-1. The control variety AC4 (29.02%) was ranked the 18th among the selected hybrids (Table 3).

Table 3. Ranked order of means for yield, nut weight, kernel weight and %0T of 26 selected elite hybrids developed in 1996 at Chambezi Bagamoyo, Eastern part of Tanzania

No	Hybrid	Y2011	Y2012	Y2013	Y2014	Y2015	Y2016	Y2017	Y2018	NutWt	KernWt	%OT
1	C9-3	4.10c-f(12)	4.59c-f(17)	8.35c-k(18)	19.14g(27)	15.61e-f(20)	20.91f-i(22)	10.41d-i(12)	10.15f(27)	10.18a(1)	3.10a(1)	30.47b-h(11)
2	C13-2	4.43b-e(7)	6.05b-d(8)	11.72a-b(2)	26.98a-g(12)	18.41a-e(5)	27.76b-e(7)	16.88a-c(3)	13.73d-f(25)	9.53ab(2)	2.63b-d(5)	27.64h-j(26)
3	C7-1-13	4.89b-d(4)	4.58c-f(19)	9.18a-g(14)	26.09a-g(16)	19.57a-d(4)	26.48b-f(11)	19.37a(1)	21.08b-e(9)	9.50ab(3)	2.74bc(3)	28.99d-h(18)
4	C19-4	3.39d-f(19)	4.59c-f(17)	7.38f-g(21)	21.22f-g(21)	14.43f(27)	20.3g-i(23)	10.43d-i(11)	35.70a(2)	9.22a-c(4)	2.79b(2)	31.00a-e(6)
5	C4-1	6.61a(1)	6.63b-c(4)	12.97a(1)	24.61c-g(18)	14.90e-f(24)	18.82g-i(25)	3.76kl(26)	18.97b-f(13)	9.22a-c(5)	2.19h-j(24)	24.3j-l(27)
6	C7-2	4.31b-e(11)	5.27b-e(15)	10.08a-f(10)	26.37a-g(14)	20.00a-c(3)	24.25c-g(16)	13.63b-e(6)	18.39b-f(14)	9.10a-d(6)	2.64b-d(4)	28.62e-h(20)
7	C14-4	2.56f-g(23)	4.51c-f(20)	11.22-d(5)	19.25g(25)	15.19e-f(22)	23.59c-g(17)	17.38ab(2)	17.88b-f(15)	8.98a-d(7)	2.62b-d(6)	29.26d-h(17)
8	C13-1	4.750b-d(5)	5.54b-e(13)	9.173a-g(15)	28.41a-f(10)	16.17d-f(16)	26.2b-f(13)	14.70b-d(4)	25.89b(3)	8.93a-e(8)	2.59b-e(8)	29.30d-h(16)
9	C1-2	0.54h(27)	1.47h(26)	2.66h(27)	22.33d-g(19)	14.83e-f(25)	22.03e-h(21)	5.23j-l(25)	16.53b-f(19)	8.85b-e(9)	2.44b-h(15)	27.82g-i(25)
10	C1-4	5.73a-b(2)	8.69a(1)	11.44a-c(4)	34.13a(1)	14.98e-f(23)	38.2a(1)	7.39h-k(19)	20.11b-f(11)	8.77b-f(10)	2.58b-f(11)	29.37d-h(15)
11	C13-4	5.14b-c(3)	6.64b-c(3)	11.62a-b(3)	20.92f-g(23)	16.90b-f(12)	22.98d-h(19)	13.51b-f(7)	15.65b-f(21)	8.69b-f(11)	2.61b-d(7)	30.34c-h(12)
12	C5-2	1.82g-h(24)	2.34g-h(25)	6.82g(23)	21.02f-g(22)	15.77e-f(17)	16.18i(27)	6.38i-l(22)	8.22j-k(27)	8.687b-f(12)	2.59b-e(9)	30.61b-g(10)
13	**C-C**	**1.81g-h(25)**	**2.70f-h(24)**	**6.83g(22)**	**22.10e-g(20)**	**16.43c-f(14)**	**26.48b-f(12)**	**9.38e-j(15)**	**20.57b-f(10)**	**8.59b-g(13)**	**2.59b-e(10)**	**30.79b-f(9)**
14	C7-1-6	3.03e-g(22)	3.82e-g(23)	8.15d-g(19)	26.60a-g(13)	15.63e-f(19)	26.11b-f(15)	13.82b-e(5)	10.94ef(26)	8.47b-h(14)	2.55b-g(12)	30.17c-h(14)
15	C1-3	4.39b-e(9)	5.80b-e(9)	9.96a-f(11)	29.55a-f(8)	14.61e-f(26)	27.61b-e(8)	7.00h-l(20)	22.68b-d(6)	8.37b-h(15)	2.40c-i(17)	28.86e-h(19)
16	C10-4-15	4.37b-e(10)	5.63b-e(12)	7.93e-g(20)	26.36a-g(15)	16.25d-f(15)	27.13b-e(9)	9.12f-j(16)	17.12b-f(17)	8.12c-i(16)	2.25e-i(20)	27.90g-i(24)
17	C10-1	4.04c-f(15)	5.70b-e(10)	10.51a-e(8)	29.86a-f(7)	16.46c-f(13)	31.15b(3)	2.87l(27)	15.31c-f(22)	8.10c-i(17)	2.24f-i(21)	27.97f-h(23)
18	C15-2-2	3.64c-f(17)	4.58c-f(18)	6.65g(25)	20.87f-g(24)	16.97b-f(11)	19.08g-i(24)	6.02i-l(24)	40.21a(1)	7.85d-j(18)	2.44b-h(14)	31.23a-e(5)
19	C22-4	3.36d-f(21)	5.28b-e(14)	9.91a-f(13)	33.70a-b(2)	15.64e-f(18)	23.19d-h(18)	7.43h-k(18)	17.4b-f(16)	7.78d-j(19)	2.21h-j(23)	28.42e-h(22)
20	C3-1	4.04c-f(14)	5.67b-e(11)	8.90b-g(16)	28.32a-f(11)	17.37b-f(8)	26.16b-f(14)	10.44d-i(10)	15.10c-f(23)	7.66e-j(20)	2.42c-i(16)	31.71a-d(4)
21	C15-4	4.39b-e(8)	6.14b-c(7)	10.46a-e(9)	30.82a-e(6)	15.44e-f(21)	29.45bc(4)	9.81e-i(14)	23.41bcd(5)	7.65e-j(21)	2.30d-i(19)	30.22c-h(13)
22	C15-2-8	3.37d-f(20)	4.48c-f(21)	8.43c-k(17)	29.17a-f(9)	20.44a-b(2)	28.26b-d(6)	11.4d-h(9)	25.10bc(4)	7.47f-j(22)	2.47b-h(13)	33.55a(1)
23	C10-4-11	4.06c-f(13)	7.02a-b(2)	9.92a-f(12)	31.13a-d(5)	18.06a-f(6)	26.89b-e(10)	9.93e-i(13)	19.11b-f(12)	7.30g-j(23)	2.08i-k(27)	28.45e-h(21)
24	C25-3	3.682c-f(16)	6.28b-c(6)	10.712a-e(7)	33.14a-c(3)	21.23a(1)	28.79b-d(5)	12.95c-g(8)	22.3b-d(7)	7.22h-j(24)	2.23g-i(22)	30.91a-e(7)
25	C5-1	0.770h(26)	1.34h(27)	3.264h(26)	19.22g(26)	16.99b-f(10)	17.79hi(26)	6.34i-l(23)	16.89b-f(18)	7.17h-j(25)	2.32d-i(18)	32.90a-c(3)
26	C15-2-26	4.46b-e(6)	6.32b-c(5)	11.13a-d(6)	32.13a-c(4)	17.72a-f(7)	31.39b(2)	6.92h-l(21)	16.28b-f(20)	6.93i-k(26)	2.13h-j(26)	30.81b-f(8)
27	C15-3	3.469d-f(18)	3.92d-g(22)	6.652g(24)	24.71b-g(17)	17.31b-f(9)	22.13e-h(20)	8.70j-g(17)	21.95b-e(8)	6.62jk(27)	2.18h-j(25)	33.20ab(2)

Means with the same letter(s) in the same column are not significantly different following Duncan's Multiple Range Test (P ≤ 0.05); Numbers within parentheses following the le stand for rank. Y = Yield (kg), NutWt = Nut weight (g), KernWt = Kernel weight (g) and %OT = Percentage kernel out-turn

4.0 Discussion

The hybrids performed better than the control variety AC4 in terms of nut yields, nut weight, kernel weight and percentage kernel outturn. This is a clear evidence that majority of the hybrids had higher yield, nut weight, kernel weight and %OT than the control variety. By ranking the means of nut yield were 3.82 kg, 5.68 kg, 8.08 kg, 11.84 kg, 12.70 kg, 17.34 kg and 19.76 kg in year 2012, 2013, 2014, 2015, 2016, 2017 and 2018 respectively. The mean for nut yield for eight years was 19.76 kg/tree which is higher than the production per tree reported by Adeigbe et al., (2015) in Nigeria (10 kg/tree) and the improved varieties reported by Desai et al., (2010) in India (10 - 15 kg/tree). Nuts with high %OT and large kernel size attracts premium price on the cashew market (dela Cruz & Fletcher, 1997). Twelve of the hybrids have nut size greater than the control AC4 (8.59 g) which shows their superiority to other cashew materials. The range of 5.9 to 10.6 g recorded by the hybrids was the higher than 5.1 to 7.0 g reported by Gyedu-Akoto et al., (2014) of the cashew nut size in Ghana. The large nut sizes are easy to shell during processing and they also produce large kernel sizes which attract higher prices on the market. In Tanzania the selection requires the minimum nut weight of 6.5 g and maximum nut weight of 12 g (Masawe &Kapinga, 2017). The kernel weight ranged from 1.91 g to 3.06 g which was within the range reported by Blaikie et al., (2002) of 1.4 to 3.2 g. When considering %OT all the clones have good outturn which ranged from 26.2 to 32.4% except one (C4-1) which had 24.3% confirming their superiority to the control. Blaikie et al., (2002) reported on %OT range of 26% to 34%. However, these results were higher than the minimum standard % OT of 20% which is acceptable by cashew processors in Tanzania (Anonymous, 2012). The coefficients of variation (CVs) were within the acceptable range for a tree crop like cashew. Similar results of CVs have been reported by Neto et al., 1997; Kasuga, 2003; Masawe et al., 2005; Masawe 2006.

By ranking means for yield, nut weight, kernel weight and percentage outturn in 2018 revealed that ten hybrids had yield higher than control variety AC4 as well as nut weight, kernel weight and percentage outturn. However, the cashew with big nut size, kernel weight and good percentage outturn are more usable to processors. The selection of these materials was based on nut size, kernel weight, percentage kernel outturn and as well as high nuts yielding. This will implies that by adopting these hybrids after release will boost cashew production and productivity through its genetic capability in yield and nut quality.

5.0 Conclusion

Among the 26 hybrids tested, 10 gave yields higher than control variety (AC4), 12 hybrids had nuts weight higher than control, 9 hybrids had kernel weight higher than control and 8 hybrids have %OT higher than control variety used. Hybrids C9-3, C13-2, C7-1-3, C19-4, C4-1, C7-2, C14-4, C13-1, C1-2, C1-4, C13-4 and C5-2 are recommended for commercialization particularly in areas with similar climatic conditions as Chambezi Bagamoyo.

6.0 Acknowledgements

The authors would like to acknowledge funding from the Government of Tanzania through the Ministry of Agriculture, Food Security and Co-operatives, Tanzania Agricultural Research Institute-Naliendele for conducting this study and to insure funds were timely available. We are very grateful to Messrs Dickson Malulu, Ms Stela Mfune, Ms Mariam Shomari, Ms Lucy Kitwange Ms Elizaberth Chale, and Ms Bertha Jamvia for taking lead in data collection, compilation and computerisation. Many thanks go to Messrs George Lucas for his invaluable contribution in maintaining trials and supervision of data recording. We appreciate the contribution of our drivers Messrs Twalib Mmole and Salimu A. Salimu.

References

Adeigbe O.O., Olasupo F.O., Adewade B.D. &, Muyiwa A.A., 2015. A review on cashew research and production in Nigeria in the last four decades. Academic journal.10 (5).196-209.

Anonymous. 2010 & 2012. Annual Cashew Research Report for 2010/2011 and 2012 seasons. Ministry of Agriculture, Livestock and Fisheries Tanzania.

Blaikie S. O'Farrell P., Warren M., Wei X., Scott N., Sykes S. & Chacko E., 2002. Assessment and selection of New Cashew Hybrids Enviromentally friendly paper, Canprint. Publication number 01/177, 29p.

Dadzie A.M., Adu-Gyam I, Opoku P.K.K., Yeboah S.Y., Akpertey J., Opoku-Ameyaw A.,Assuah K.M., Gyedu-AkotoE. & Danquah W. B., 2014. Evaluation of potential cashew clones for utilization in Ghana. Advances in Biological Chemistry, 4, 10.

Dela-Cruz F.S. & Fletcher R.J., 1997. Identification of superior Cashew Trees from seedling Population. Crop Science Society of the Philippines, 22(2), 83-88.

Dendena B. & Corsis S., 2014. Cashew, from seed to market review. Agronomy for Sustainable Development, 34 (4), 753-772.

Desai A.R., Faleiro J.R., Thangam M., Priya Devi S., Safeena S.A. and Singh N.P. 2010. Techniques and Practices for Cashew Production. Technical Bulletin, 21, ICAR Research complex for Goa, Ela, Old Goa-403402, GOA, I NDIA.

ECI Africa, 2003. Cashew nut sub-sector study final report, October 2003. Development Alternative Inc-Private Enterprise support Activities Project Tanzania, 73 p.

Gyedu-Akoto E. Lowor S.T., Assuah M., Kumi W. and Dwomoh E., 2014. Assessment of Post –Harvest Handling Effects on Quality of Cashew nuts and Kernels in Ghana. Journal of Scientific Research and Report, 3 (7), 953-965.

Kasuga L.J.F., 2003. Adoption of improved cashew (Anacardium occidentale L.) by smallholder farmers in south eastern Tanzania. PhD thesis: University of Reading, Reading (UK).

Majune, D.J, Masawew, P.A, & Mbega E.R. 2018a. Current Status of Cashew Leaf and Nut Blight Disease (Cryptosporiopsis spp.) and Screening of Elite Cashew Hybrids Developed in 1996 and 1998 against the Disease in Eastern and Southern Tanzania. Research in Plant Disease. 24(4):265-275(2018)

Majune, D.J., Masawe, P.A., & Mbega, E.R., 2018b. Status and Management of Cashew Disease in Tanzania. International Journal of Environment, Agriculture and Biotechnology (IJEAB) Vol-3, Issue-5, Sept-Oct- 2018.

Masawe P.A.L., 1994. Aspects of breeding and selecting improved cashew geotypes (*Anarcadium occidentale L.*) PhD thesis:University of Reading , Reading (UK).

Masawe P.A.L., 2006. Tanzania Cashew Cultivars: Selected Clones. 1st Ed.Colour Print (T) Ltd, Dar Es Salaam, Tanzania.

Masawe P.A.L., Mfune S. & Mbunda Z., 2005. Performance of cashew hybrids developed from partial diallel crossing between selected clones in Tanzania. Tanzania Agricultural Research and Training Newsletter, 20(1-4), 5-8.

Masawe P.A.L., 2009. Modern Agro-practices in cashew. Journal of Science, Technology and Management, 2, 9-16.

Masawe, P. A. L and F. A. Kapinga (2017). The First Dwarf Cashew Varieties in Tanzania. Cashew Research Programme, Naliendele Agricultural Research Institute. Colour Print Tanzania Limited.

Neto V. & Caligari P.D.S., 1997 .The effect of variability on cashew yield trials.In: Topper C.et al (Eds).Proceedings of the international cashew and coconut conference, p.74-75, 17-21 February 1997, Dar –es-salaam, Tanzania.

Ohler J.G., 1979. Cashew Communication 71. Deartment of Agricultural Research, Koninklijk Institnutvoor de Tropen, Amsterdam, 260p.

Sijaona M.E.R., 2009. Evaluation of Sulphur formulations against powdery mildew diseases on cashew. Paper submitted to Registar of Pesticides TPRI, Arusha – November 2009.

Woodroof J.G., 1979. Tree nuts.2nd.Westport, Connecticut: AVI Publishing Company.

Neto V., 1992.Yield variability of cashew trees in East Africa.PhD thesois:University of Reading, Reading (UK)

USDA West Africa PRO-Cashew Project

The USDA West Africa Cashew Project (PRO-Cashew) is a five-year project ending in September 2024, implemented by CNFA in Côte d'Ivoire, Burkina Faso, Benin, Ghana, and Nigeria. The project aims to improve the cashew sector in the five implementing countries by:

- Increasing productivity and efficiency of farmers in the cashew value chain through improving crop quality, rehabilitating and renovating orchards, and strengthening the capacities of cooperatives and producer organizations, nursery systems and input suppliers.
- Boosting trade of cashew by improving harvest and post-harvest techniques, addressing gaps in data collection, analysis and dissemination, supporting supply chain linkages between farmers and agro-food companies, and encouraging harmonized market-driven regional policies.

"PRO-Cashew" represents the project's main objectives: promotion of West Africa's cashew value chain, professionalization of the regional industry, and participation of all its main actors.

Sample Activities:

- Support to cashew-processing factories to develop their supply chain by strengthening business relationships with farmers and improving product traceability and quality
- Development of a multi-country cashew data management system (Cashew-IN) that meets the needs of policy makers, farmers, and the private sector
- Support for yield improvement as well as orchard improvement and renovation
- Farmer capacity building through farmer organizations and agribusiness suppliers.

Key Achievements to Date:

- 25,540 individuals participating in USDA food security programs
- 20,979 MT of commodities sold by farms and firms receiving USDA assistance
- $16.61 million annual sales of farms and firms receiving USDA assistance
- 4 grants disbursed building market linkages with 40,000 farmers from 2022-2024

Quick Facts

Period of Performance:	2019-2024
Implementer:	CNFA
Agreement Value:	$23,100,000
US Commodity Monetized:	Rice
Direct Beneficiaries:	70,340
Indirect Beneficiaries:	359,800

US-West Africa Trade

	Total	Agriculture
Exports	$1.2b	$155m
Imports	Mostly Oil	$32m

Expected results over life of project

$133.6 million
Value of annual sales of farms and firms receiving USDA assistance

211,223 MT
Volume of commodities sold by farms and firms receiving USDA assistance

70,340
Number of individuals participating in USDA food security

106,822
Number of hectares under improved management practices

MULTI-LOCUS GWAS ANALYSIS FOR DETECTING QTLS AND CANDIDATE GENES FOR IMPORTANT MORPHOMETRIC ATTRIBUTES AND AGRONOMIC PERFORMANCES IN CASHEW *(ANACARDIUM OCCIDENTALE L.)*

Hubert ADOUKONOU-SAGBADJA[1*] & Kouami N'DJOLOSSE[1,2]

[1] Laboratory of Genetic Resources & Molecular Breeding (LaREGAME), Department of Genetics and Biotechnology, Faculty of Sciences and Techniques, University of Abomey-Calavi, BP 1947, Abomey-Calavi, Benin

[2] National Agricultural Research Institute of Benin (INRAB), CRA-Centre, BP 112 Savè, Benin

[*] Corresponding author: hadoukas@gmail.com; Tél. (+229) 95 85 28 38 / 96 72 76 05

Abstract

Cashew (Anacardium occidentale L.) is the second most important cash crop in Benin after cotton and contributes significantly to the local economy. However, the limited genomic resources available in this crop impedes the breeding efforts to develop improved planting materials with high agronomic performances. Therefore, we used genome-wide association mapping approach on a large panel of 208 Beninese cashew trees to generate useful genomic resources for genetic improvement of cashew crop. Ten quantitative traits related to cashew tree attributes (age, height and spread), yield performance and related traits in nut, kernel and apple were investigated. A total of 10,054 Single Nucleotide Polymorphism '(SNPs) were used to identify significant Quantitative Traits Nucleotides (QTNs) and candidate genes controlling these traits using six multi-locus genome-wide association study methods. As a result, a total of 54 significant QTNs were globally detected in which 60% controlling the apple parameters (length, width and weight) while 30% of them were tightly linked to nut yield (12%), nut weight (2%) and kernel attributes (16%). Gene content analysis of the clustered regions revealed the presence of 29 candidate genes, including beta-amylin synthase-like, MDIS1-interacting receptor like kinase 2-like, serine/threonine-protein kinase SRK2A-like, IAA-alanine resistance protein 1-like, homologous protein of regulatory subunit 6 of 26S non-ATPase proteasome, MAH1-like alkane hydroxylase, and aluminum-activated 9-like malate transporter. These results showed that GWAS can be employed as effective strategy to identify candidate genes and offered a good prospect for improving nut and apple productivity traits in cashew.

Keywords: Cashew, genomic breeding, GWAS, Marker-Assisted selection, QTLs, SNPs

Introduction

Cashew (Anacardium occidentale) is a member of the family Anacardiaceae that includes about 80 genera and 870 species of evergreen or deciduous trees, shrubs, and woody vines. They are native to tropical and subtropical areas of the world with only few species occurring in temperate regions. Just as mango (Mangifera indica) and pistachio (Pistacia vera), cashew is among the most economically important fruit and nut crops of the family. Kernels from cashew nuts are highly nutritious (Sethi et al., 2015). It contains about 21% proteins, 23% carbohydrates and 46% fats, which contribute to lowering cholesterol levels in the body (Aremu et al., 2006). These nutritional attributes contribute to the high commercial value of cashew nuts and apples (Akinwale, 2000; Savadi et al., 2020).

In Africa, cashew nut is cultivated in varying degrees in different countries (Ndiaye et al., 2021). Benin is among the major cashew producing countries, ranking among the top 10 producers worldwide and fourth in the West African sub-region (Tandjiékpon, 2010, Ricau, 2019). Cashew nuts are the second most important export crop for the country after cotton, accounting for 7% of agricultural GDP and 3% of national GDP in Benin (Tandjiékpon, 2010). Although the cashew sector is booming in Benin due to an increase in cultivated area, the average nut productivity is very low (2-3kg/tree) compared to major producing countries in the world which reach 15kg/tree (Kodjo et al., 2016; N'djolossè et al., 2019). Therefore, the main challenge in increasing cashew productivity is to develop new planting material with high nut yield potential. Selection of high-yielding varieties is often the focus of cashew breeding programs, although yield is usually difficult to improve due to its complexity. According to Savadi et al. (2020), breeding new cashew cultivars using conventional breeding is time-consuming, unpredictable, and often crowned with limited success. Instead of classical methods, the advent of molecular tools has enabled the identification of genomic regions harboring the inheritance of quantitative (Bhadmus et al., 2022). According to Bhagya et al (2020), genome-wide association studies (GWAS) is an important approach that can be employed to identify Quantitative Trait Loci (QTL) associated with important traits and their further use in marker assisted selection (MAS).

In cashew, there are few reports on molecular breeding and QTL analyses, except those reported by Cavalcanti and Wilkinson (2007), Cavalcanti et al. (2012) and dos Santos et al. (2011). These studies, based on a bi-parental F1 population, used dominant markers such as AFLP and RAPD which generated low genetic density maps with few QTLs detected for yield traits and physicochemical traits. Mzena et al. (2017) identified 13 QTLs associated with yield, quality, and plant size in cashew by developing a SNP-based linkage map.

With the recent progress in genotyping by sequencing (GBS) and the relative ease of obtaining important genome-wide SNP data, their impact on complex trait can be tracked by QTL mapping or by GWAS approach (Peltier et al., 2019). When these SNPs are statistically linked to a phenotype, they become quantitative trait nucleotides (QTNs) that have been widely used in many animal as well in plant breeding research programs (Brachi et al., 2011; Sharma et al., 2015; Cui et al., 2018, Kpoviessi et al., 2022). The objective of the present study was therefore to identify QTNs and candidate genes associated with important morphometric and agronomic traits in cashew using multi-locus GWAS approach.

Materials and Methods

Plant material and phenotypic evaluation

A total of 208 cashew trees were sampled from farmers' plantations in the three regions favorable for cashew production in Benin, covering three agro-ecological zones (AEZ) and nine administrative districts. The sampling covers the genetic variability present in the cultivated cashew in Benin Republic (N'Djolosse et al. 2020). The phenotyping focused on ten quantitative agronomic traits using cashew descriptors (IBPGR, 1986). These were age of the trees, tree height and canopy spread, nut yield, nut weight, kernel weight, kernel rate, apple length, apple width and apple weight were measured. Data collection was carried out from 2018 to 2020.

Genotyping

Leaf samples of the 208 selected cashew trees were collected from the fields and immediately stored as source materials at the Laboratory of Genetic Resources and Molecular Breeding (LaREGAME), University of Abomey-Calavi (Benin). Five to six discs of oven-dried leaf from the source materials were sampled into three 96 wells sample collection plates and shipped to the SEQART AFRICA based at International Livestock Research Institute in Nairobi (Kenya) for genotyping. The genomic DNA was extracted from cashew leaf materials using the Nucleomag Plant DNA extraction kit. For the genotyping, Diversity Arrays Technology sequencing (DArT-seq) was used. Genomic libraries construction, their complexity reduction and purification as well as the Next Generation Sequencing (NGS) in Illumina Hiseq2500 were conducted following methods described by Kilian et al. (2012). The DArTseq markers scoring was achieved using DArTsoft14 and the reads were aligned to the reference genome of mango, a related species of cashew (Anacardiaceae), to identify chromosome positions (https://mangobase.org/ftp/). After filtration, 10,054 SNPs were found informative that can be used for further analyses. The complete procedure is described by Mzena et al. (2017).

Multi-Locus GWAS analysis and candidate genes identification

GWAS analysis was conducted based upon the inferred phenotypic and molecular data. The mrMLM V4.0.2 (Zhang et al., 2020) in R package (https://cran.rproject.org/web/packages/mrMLM/index.html), including six multi-loci GWAS models (FASTmrMLM, mrMLM, pKWmEB, pLARmEB, FASTmrEMMA and ISIS EM-BLASSO), was used to test the association between the 10,054 informative SNPs dataset and mean performance values for cashew phenotypic traits following the methodological approach employed by Miesho et al. (2019) and Kpoviessi et al. (2022). The single trait-single environment association mapping procedure (Egbadzor et al., 2013; VSN International, 2012) was followed to identify SNP markers that are linked to the mean performance of phenotypic traits recorded. Kinship matrix (K matrix) were estimated to infer the cryptic relatedness and population structure using the software TASSEL5.2.48 (Bradbury et al. 2007). The linkage disequilibrium for the effective control of the population structure was carried out with GAPIT version 3. Quantile- quantile (QQ) plots were used to assess the presence of effective associations. Default parameters were considered for all the six multi-locus models used here (Zhang et al., 2020). Mango genome was used as reference for the potential candidate genes retrieving. The annotated functions and their relevance to the cashew tree productivity were determined per candidate genes using NCBI website (https://www.ncbi.nlm.nih.gov/gene/?term=Mangifera+indica+genome).

Results and discussion

Genetic variability within the cashew germplasm analyzed

Reliable phenotypic and genotypic data are important for accurate GWAS analysis (Kang et al. 2020). In this study, a high level of phenotypic variation among the tested genotypes were observed (Table 1). The tree yield showed the highest variation followed by the apple weight, tree spread, tree height and kernel weight. The range of variation observed was more than10% for all traits. This range of variation in phenotypic records in cashew traits was also reported in other studies (Chabi-Sika et al. 2015, N'Djolosse et al. 2019, 2020). As it has been stated by Cavalcanti et al. (2012), this range of variation is great and demonstrate the usefulness of this collection in QTL detection. At molecular level, the germplasm analyzed were diverse as 10,054 SNPs were found informative after filtration and was used for genetic parameter estimation and QTL analysis. They were well distributed across the 20 chromosomes of mango, which was used as reference genome in this study. The 2D as well the 3D distributions of the cashew trees forming the study population are illustrated in figure 1. In general, the frequency distribution analysis of the markers revealed a dispersed distribution. This confirms that at molecular level, important genetic diversity exists in the analyzed cashew germplasm which may allow a good detection of QTLs. Similar results were found by Mzena et al. (2017) who obtained a high degree of variability within a segregating F2 cashew population which offered a high likelihood for identifying quantitative traits loci associated with yield, nut quality and plant size. The presence of substantial diversity in cashew germplasm is reported in Benin (Sika et al. 2015) and inCôte d'Ivoire (Kouakou et al. 2020).

Table 1. Performances of the ten quantitative traits studied in a panel of 208 cashew trees selected from the major growing areas of Benin

Quantitative traits	Minimum	Maximum	Mean	St. Dev	CV* (%)
Tree parameters:					
Tree age	7	35	13.2	3.2	24
Tree height (m)	3.2	14.4	7.0	2.0	28
Tree spread (m)	3.6	20.3	9.7	2.8	29
Tree yield (kg nut/tree)	0.0	85	18.0	14.8	82
Nut and Kernel parameters:					
Nut weight (g)	2.6	9	6.1	1.2	20
Kernel weight (g)	0.7	3	1.6	0.5	28
Kernel percent (%)	16.8	36.7	27.3	2.6	10
Apple parameters:					
Apple length (cm)	2.9	9.8	6.0	1.4	22
Apple width (cm)	1.1	6.4	3.6	0.8	22
Apple weight (g)	16.8	119	71.4	22.6	32

*Coefficient of variation

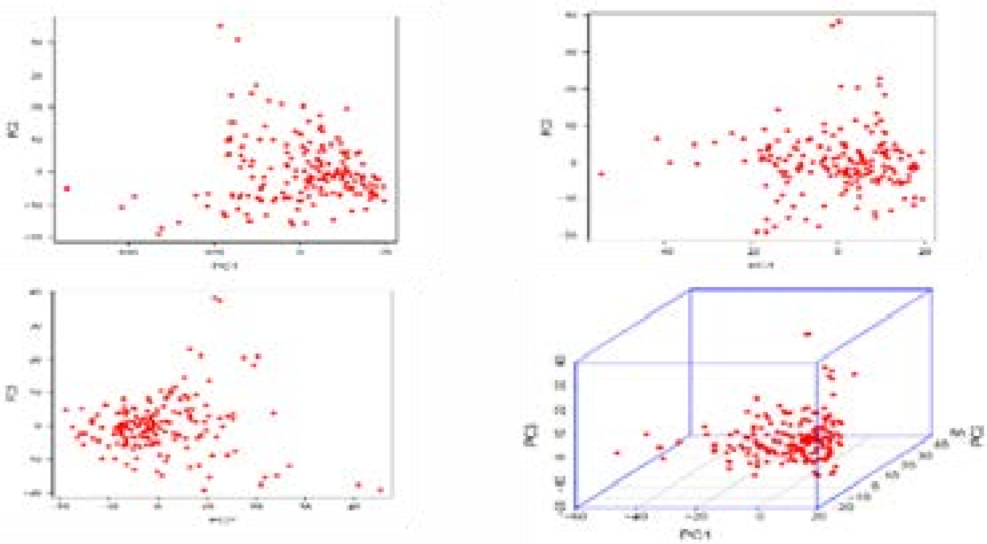


Figure 1: 2D and 3D scatter plots of PCs illustrating the distribution of cashew genotypes

Multi-locus GWAS QTNs and candidate gene detections

Compared with other mapping approaches, GWAS is known as a power option for the genetic characterization of quantitative traits (Cui et al. 2018). In the use of six multi-locus GWAS approach of mrMLN package to detect QTLs, a total of fifty (50) significant QTNs (LOD-score > 3.00) were obtained. These are distributed on 12 annotated chromosomes of mango reference genome. The chromosomes are 1, 3, 4, 5, 9, 11, 12, 13, 15, 17, 19 and 20. The highest number of QTNs of 9, 8 and 8 were found on chromosomes 20, 1 and 3 respectively (Figure 2). On the other hand, chromosomes 9, 11 and 19 had one QTN each. These 50 QTNs were variably detected by one multi-locus model while some were simultaneously detected by 2 to 3 different models. Out of the 6 models used, 4 detected 50 QTNs, attesting to the efficacy of the multi-locus GWAS in detecting QTNs. The robustness of this approach compared to single-locus GWAS has been largely proven by Segura et al. (2012) and Cui et al. (2018). This differential distribution of QTLs across the chromosomes could be linked to the evolutionary history of the cashew tree crop.

In other studies, Cavalcanti et al. (2002) used a bi-parental F1 population and identified 11 QTLs in which three were related to nut weight. Mzena et al. (2017) also developed a SNP-based linkage map and identified 13 QTLs associated with yield, quality, and plant size in cashew. In this study, 60% of the detected QTNs controlled apple parameters (length, width and weight) while 30% of them were tightly linked to nut yield (12%), nut weight (2%) and kernel (16%) attributes (Figure3). For most of the traits studied, many of the identified QTNs showed a high percentage of phenotypic variance explained (%PVE) of more than 10% suggesting that these QTNs are effective. Besides, some of them were detected by more than one multi-locus model. These results corroborate those of Mzena et al. (2017) and Anderson et al. (2013) who also reported similar observations by highlighting that the higher the %PVE, the higher the existence of true QTLs. Comparison of detected QTLs with previously reported ones in cashew was difficult due to the differences in approaches used and the location of their expression. However, the new QTNs obtained in the present study can complement the QTLs of previous studies (Cavalcanti et al. 2012, Mzena et al. 2017) to facilitate their use in cashew breeding.

.

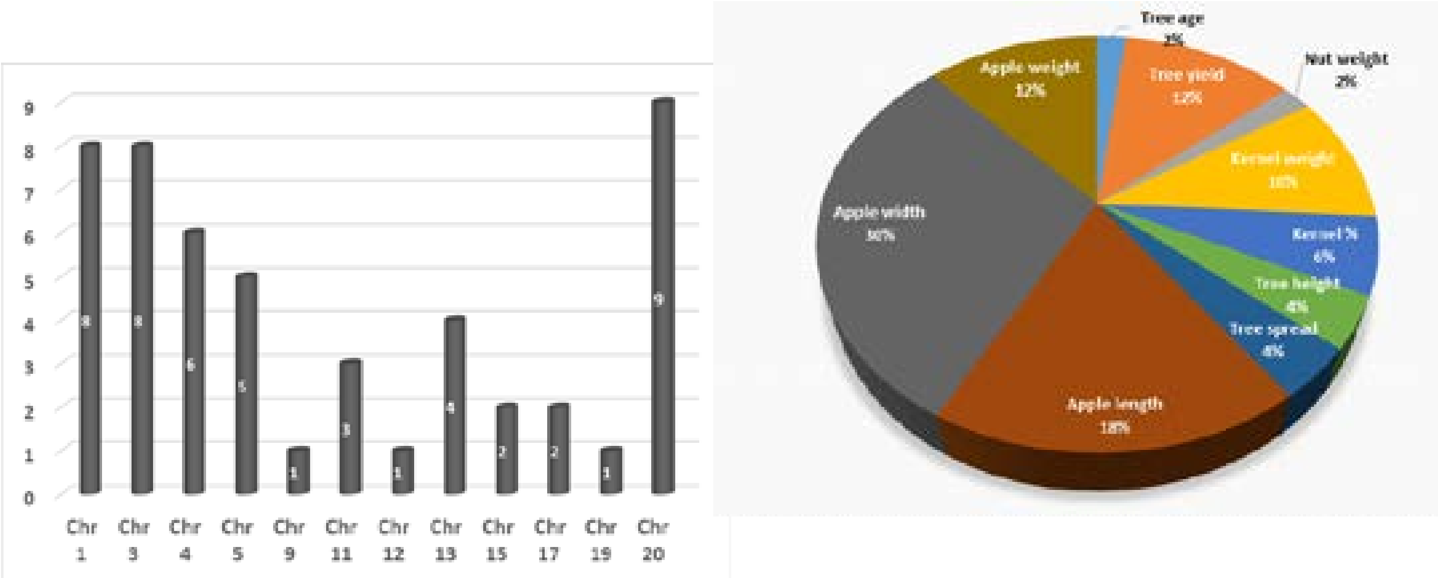


Figure 2: Distribution of the number of QTNs through the annotated chromosome v2 mango (Mangifera indica) reference genome chromosomes and their proportion per studied trait in cashew

Some QTNs were found to be significantly associated with single traits. For instance, tree age and nut weight were associated with a single QTN located on chromosomes 3 and 4 with a PVE of 8.40% and 3.4%, respectively. In contrast, others were simultaneously linked with several traits. For instance, five (5) QTNs were linked to tree yield obtained after three years (2018- 2020) of observation with a PVE between 3.40% and 13.80%. Kernel weight was associated with 4 QTNs with a PVE varying from 3.50% to 12.12%. The % kernel outturn was associated with 3 QTNs on 3 different chromosomes (3; 15 and 17) with a PVE between 4.20% and 14.60%. Tree height and canopy spread were linked to 2 QTNs located respectively on 2 chromosomes (13 and 19) and 1 chromosome (13) with PVE of 16.50%; 13.90% and 7.20%; 4.30% respectively. Apple length was associated with 4 QTNs located on chromosomes 1, 20, 4 and 3 with PVE between 6.11% and 22.22%. The apple width was associated with 12 QTNs with PVE varying between 5.40% and 32.32%. Apple weight was associated with 3 QTNs with PVE recorded between 10.11% and 17.02%.

A collocation of QTL for different traits is recognized as an indicator for pleiotropic effect of the given loci. In the present study, divers QTNs controlling several traits have also been identified. It is the case of a multi-trait QTN located at the position 6352637 bp on chromosome 15 controlling kernel weight and % outturn. The QTNs were detected at the position 817675 bp on chromosome 1 for apple weight; apple width and apple length. Pleiotropic QTNs involved in the control of several traits have also been reported by Argyris et al. (2005) and could be due to common regulatory mechanism for these traits (Clerkx et al. 2004).

Several candidate genes have been determined in connection with the different QTNs associated with the traits studied. A total of 29 candidate genes were found to be linked to the studied traits (Table 4). The study of the annotations toadied the determination of the functions of the different genes in the cashew plant. All these genes identified by their product were expressed in different ways. In general, the physiological functioning of the plant is associated with molecular characteristics related to gene expression. These different characteristics include beta-amyrin synthase-like, MDIS1-interacting receptor like kinase 2-like, serine/threonine-protein kinase SRK2A-like, IAA-alanine resistance protein 1-like, Homologous protein of regulatory subunit 6 of 26S non-ATPase proteasome, MAH1-like alkane hydroxylase, and aluminum-activated 9-like malate transporter. These candidate genes provide better clues for breeding cashew genotypes (Cui et al. 2018; Kpoviessi et al. 2022).

Conclusion

In this study, a multi-locus GWAS methodological approaches was used to detect 50 QTNs and 29 candidate genes associated with 10 important agronomic traits in Benin. These genes, through their expressed protein products, are directly or indirectly involved in the physiological functioning of the cashew plant. This study demonstrates the potential of employing the use of genomic resources that offer the early selection and release of new cashew varieties to increase productivity. However, these predicted candidate genes require further validation using segregating populations to determine their functions in breeding new cashew genotypes, especially their propensity to boost cashew productivity.

Acknowledgment

This study was supported by GIZ through Cashew Funds Initiative.

References

Anderson J. A., Sorells M., E., Tanksley S., D. (1993) RFLP analysis of genomic regions associated with resistance to preharvest sprouting in wheat. Crop Science 33:453-459

Argyris J, Truco M, J, Oshoa O, Knapp S, J, Still D, W, Lensen G, M, Schut J, W, Michelmore R, W, Bradford K, J (2005) Quantitative trait loci associated with seed and seedling traits in Lactuca.

Aremu, M. O.; Olonisakin, A.; Bako, D. A. and Madu, P. C. (2006). Compositional studies and physicochemical characteristics of cashew nut (Anacardium occidentale L.) flour. Pakistan Journal of Nutrition 5 (4): 328-333.

Akinwale T. 2000. Cashew apple juice: its use in fortifying the nutritional quality of some tropical fruits. Eur Food Res Technol, 211, 205–207. https://doi.org/10.1007/s002170050024

Bhadmus O. A., Badu-Apraku B., Adeyemo O. A., Agre P. A., Queen O. N., Ogunkanmi A. L. 2022. Genome-Wide Association Analysis Reveals Genetic Architecture and Candidate Genes Associated with Grain Yield and Other Traits under Low Soil Nitrogen in Early-Maturing White Quality Protein Maize Inbred Lines. Genes 2022, 13, 826. https://doi.org/10.3390/genes13050826.

Bhagya HP, Babu BK, Gangadharappa PM, Mahantesha Naika BN, Satish D, Mathur RK. (2020). Identification of QTLs in oil palm (Elaeis guineensis Jacq.) using SSR markers through association mapping. J Genet. 2020. https://doi:10.1007/s12041-020-1180-4

Brachi, B., Morris, G. P., and Borevitz, J. O. (2011). Genome-wide association studies in plants: the missing heritability is in the field. Genome Biol. 12, 232. https://doi:10.1186/gb-2011-12-10-232

Bradbury, P. J., Zhang, Z., Kroon, D. E., Casstevens, T. M., Ramdoss, Y., & Buckler, E. S. (2007). TASSEL: Software for association mapping of complex traits in diverse samples. Bioinformatics, 23(19), 2633–2635. https://doi.org/10.1093/bioinformatics/btm308

Cavalcanti, J. J. V., Wilkinson, M. J. (2007). The first genetic maps of cashew (Anacardium occidentale L.). Euphytica (2007) 157 :131–143. DOI 10.1007/s10681-007-9403-9

Cavalcanti, J. J. V. ; Dos Santos, F. H. C. ; Da Silva, F. P. ; Pinheiro, C. R. (2012). QTL detection of yield-related traits of cashew. Crop Breeding and Applied Biotechnology, Viçosa, MG, v. 12 (1): 60-66

Chabi-Sika, K.; Adoukonou-Sagbadja, H.; Ahoton, L.; Adebo, I.; Adigoun, F. A.; Saidou, A.; Ahanchede, A.; Kotchoni, S. O.; Baba-Moussa, L. (2015). Morphological characterization and agronomic performances of cashew (Anacardium occidentale L.) accessions from Benin Journal of Agricultural and Crop Research Vol. 3(2), pp. 27-40, ISSN: 2384-731X

Clerkx EJM, El-Lithy ME, Vierling E, Gerda RJ, Blankestijn-De Veries H, Groot SPC, Vreugdenhil D, Koornneef M (2004) Analysis of allelic variation of Arabidopsis seed germination and seed longevity traits between the accessions Lsberg erecta and Shakdara, using a new recombinant inbred line population Plant Physiology 135:432-443

Cui, Y., Zhang, F., & Zhou, Y. (2018). The application of multi-locus GWAS for the detection of salt-tolerance loci in Rice. Frontiers in Plant Science, 9, 1464. https://doi.org/10.3389/fpls.2018.01464

dos Santos, F. H. C.; Cavalcanti, J. J. V.; and da Silva, F. P. (2011). QTL detection for physicochemical characteristics of cashew apple. Crop Breeding and Applied Biotechnology 11: 17-26, 2011 Brazilian Society of Plant Breeding. Printed in Brazil.

Egbadzor K. F., Yeboah M., Danquah E. Y., Ofori K., Offei S. K. 2013. Identification of SNP markers associated with seed size in cowpea [Vigna unguiculata (L) Walp]. International Journal of Plant Breeding and Genetics, 7(2):115-123.

IBPGR. 1986. Cashew Descriptors. International Board for Plant Genetic Resources, Rome. 36p.

Kang Y, Barry K, Cao Fangbing, Zhou M (2020) Genome-wide association mapping for adult resistance to powdery mildew in common wheat. Molecular Biology Reports 47:1241-1256

Kilian, A., Wenzl, P., Huttner, E., Carling, J., Xia, L., Blois, H., Caig, V., Heller-Uszynska, K., Jaccoud, D., Hopper, C., AschenbrennerKilian, M., Evers, M., Peng, K., Cayla, C., Hok, P., & Uszynski, G. (2012). Diversity arrays technology: A generic genome profiling technology on open platforms. Methods Molecular Biology, 888, 67–89. https://doi.org/10.1007/978-1-61779-870-2_5

Kouakou C. K., Adopo A. N., Djaha A. J-B., N'da D. P., N'da H. A., Zoro Bi I. A. Koffi K. K., Djidji H., Minhibo M. Y., Dosso M., N'Guessan A. É. 2020. Genetic characterization of promising high-yielding cashew (Anacardium occidentale L.) cultivars from Côte d'Ivoire. Biotechnol Agron Soc Environ, 24:46–58.

Kpoviessi, A. D., Agbahoungba, S., Agoyi, E. E., Badji, A., Assogbadjo, A. E., Chougourou, D. C., & Adoukonou-Sagbadja, H. (2022). Application of multi-locus GWAS for the detection of bruchid resistance loci in cowpea (Vigna unguiculata). Plant Breeding, 141(3), 439–450. https://doi.org/10.1111/pbr.13014

Miesho, B.; Hailay, M.; Msiska, U.; Awio, B.; Malinga, G. M.; Ongom, P. O.; Edema, R.; Gibson, P.; Rubaihayo, P. and Kyamanywa, S. (2019). Identification of candidate genes associated with resistance to bruchid (Callosobruchus maculatus) in cowpea. Plant breeding 1-9. https://doi.org/doi:10.1111/pbr.12705

Mzena, G. P.; Kusolwa, P. M.; Rwegasira, G. M. and Yao, N. K. (2017). Mapping of quantitative trait loci (QTL) related to yield, nut quality and plant size of cashew (Anacardium occidentale L). International Journal of Agriculture, Environment and Bioresearch. 2 (6): 303-323.

N'Djolossè K., Adoukonou-Sagbadja H., Gbèmavo C. D. S. J., Kodjo S., Badou A., Maliki R., Ahoyo Adjovi N. R. 2019. Agro-morphological characterization of preselected cashew (Anacardium occidentale L.) mother trees in Benin farmer's plantations. Journal of Agriculture and Environment for International Development (JAEID), 113(1), 17-34. https://doi.org/10.12895/jaeid.20191.841.

N'djolossè, K., Adoukonou-Sagbadja, H., Gbèmavo, C. D. S. J., Kodjo, S., Badou, A., Maliki, R., & Ahoyo Adjovi, N. R. (2019). Agro-morphological characterization of preselected cashew (Anacardium occidentale L.) mother trees in Benin farmer's plantations. Journal of Agriculture and Environment for International Development (JAEID), 113(1), 17-34. https://doi.org/10.12895/jaeid.20191.841.

N'djolosse, K. ; Adoukonou-Sagbadja, H. ; Maliki, R. ; Kodjo, S. ; Badou, A. ; et Ahoyo Adjovi, R. N. (2020). Performances agronomiques des arbres-mères d'anacardiers (Anacardium occidentale L.) sélectionnés dans les plantations paysannes au Bénin. Int. J. Biol. Chem. Sci. 14(5): 1536-1546, June 2020. DOI : https://doi.org/10.4314/ijbcs.v14i5.4

Ndiaye, S.; Charahabil, M. M. and Diatta M. (2021). Caractéristiques des plantations d'anacardiers (Anacardium occidentale L.) et déterminants économiques des exploitations en Casamance. Vertigo. https://doi.org/10.4000/vertigo.28723

Peltier, E.; Friedrich, A.; Schacherer, J.; Marullo, P. (2019) Quantitative Trait Nucleotides Impacting the Technological Performances of

Industrial Saccharomyces cerevisiae Strains. Front. Genet. 10:683. https://doi.org/10.3389/fgene.2019.00683

Ricau P. (2019). The West African cashew sector in 2018: General trends and country profiles. Nitidae, p. 30.

Savadi, S., Muralidhara, B.M. & Preethi, P. (2020). Advances in genomics of cashew tree: molecular tools and strategies for accelerated breeding. Tree Genetics & Genomes 16, 61 (2020). https://doi.org/10.1007/s11295-020-01453-z

Sethi, K.; Lenka, P. C.; Tripathy, P. (2015). Studies of heterosis in cashew (Anacardium occidentale L.) In: Compendium of abstracts of the 2nd international conference on bio-resource and stress management, ANGRAU & PJTSAU, Hyderabad, India, 7-10 January 2015.

Sharma, A., Lee, J. S., Dang, C. G., Sudrajad, P., Kim, H. C., Yeon, S. H., et al. (2015). Stories and challenges of genome wide association studies in livestock-a review. Asian-Australas. J. Anim. Sci. 28, 1371–1379. https://doi.org/doi:10.5713/ajas.14.0715

Sika K. C., Adoukonou-Sagbadja H., Ahoton L., Saidou A., Ahanchede A., Kefela T., Gachomo E. W., Baba-Moussa L., Kotchoni S.O. 2015b. Genetic Characterization of Cashew (Anacardium occidentale L.) Cultivars from Benin. J Horticulture 2 :153, https://doi.org/doi:10.4172/2376-0354.1000153

Tandjiékpon A. M. (2010). Analyse de la chaine de valeur du secteur anacarde du Bénin. Rapport d'étude, Initiative du Cajou Africain (ICA/GIZ), Bénin. 62 p.

Zhang, Y.-W., Lwaka Tamba, C., Wen, Y.-J., Li, P., Ren, W.-L., Ni, Y.-L., Gao, J., & Zhang, Y.-M. (2020). mrMLM v4.0: An R platform for multilocus genome-wide association studies. Genomics, Proteomics & Bioinformatics, 18, 481–487. https://doi.org/10.1016/j.gpb.2020.06.006 13: 402-403

Swain B.K., Naik P.K. and Singh N.P. 2014. Unconventional feed resources for efficient poultry production. Technical Bulletin 47:1-55

Thirumalaisamy G.,Purushothaman M.R., Vasantha Kumar P. and Selvaraj P. 2016. Effect of feeding cotton seed meal on some haematological and serum biochemical parameters in broiler birds. Veterinary World. 2016 July; 723-727 doi:10.14202/vetworld.2016.723-727

Yisa I.K. 2019. Utilisation of Cashew (Anacardium occidentale L.) apple pomace as a source of energy by broiler Ph,D Thesis http://repository.pgcollegeui.com

IMPACT ASSESSMENT OF GOOD AGRICULTURAL PRACTICES TRAINING ON THE YIELD AND INCOME OF CASHEW NUT PRODUCERS IN CÔTE D'IVOIRE

M. M. Traore[1,2]*, Z. Ballo[3], P. Zahonogo[4]

[1] Alassane Ouattara University, 18BP V18 Bouaké, Côte d'Ivoire.

[2] Cashew Research and Development Network in Africa (REDAA), 22 BPM 1027 Abidjan 22, Côte d'Ivoire.

[3] Félix Houphouët Boigny University, BP V34 Abidjan 01, Ivory Coast.

[4] Thomas Sankara University, 04 BP 8938 Ouagadougou, Burkina Faso.

*Corresponding author: ellatraore87@gmail.com.

Abstract

Diseases and pests limit cashew productivity. In Ivorian cashew farms, they cause significant production losses which in some cases can reach 90%. This poses a great danger to production and household income. The generally low agricultural income affects the well-being of rural households and it is imperative for the Ivorian government to find appropriate solutions. The major challenge for agricultural research is to develop technological innovations to increase the yield of crops and ensure the sustainability of these crops in order to contribute to achieving food security and alleviating poverty. The Ivorian government has put in place intentional strategies for the modernisation and transformation of agriculture through the transfer of cultural and technical innovations in rural areas. Since 2014, the National Rural Development Support Agency has been training cashew producers in Good Agricultural Practices (GAPs). However, it has been observed that cashew producers adopt few of the GAPs (10%). The objective of this study therefore is to assess the impact of the training in the use of GAP on the yield and income of cashew growers. Data was obtained from 319 farmers in the Gbêkê and Poro regions. They included 44.8% of producers who have not received training and 55.2% who have received GAP training. The methodology adopted is the Rosenbaum and Rubin matching approach. Our results revealed a significant yield gain for all the producers. The gain was quite significant for growers with infected farms. Additionally, the training has a significant positive impact on the income of the producers. It would be advisable to put in place strategies for the control of cashew diseases and pests and to continue to improve the awareness of producers on compliance with GAP.

Keywords: Cashew, Evaluation of impact, GAP, Yield, Income, Côte d'Ivoire.

Introduction

The overall low level of agricultural income is a constraint to household welfare, particularly rural households. The agricultural productivity rate of Sub-Saharan Africans per worker is the lowest in the world. The annual average agricultural productivity per worker from 2005-2015 was 1,109.30 USD while that of the Organization Economic Cooperation Development (OECD) was 19,540.80 USD, 5,394.90 USD for the Middle East and North Africa (UNDP, 2017). In terms of crop yield, Africa (1,421.8 kg/ha) is almost 3.5 times lower than East Asia (4,809.1 kg/ha) (UNDP, 2017). Nearly 70% of the poor on the entire continent are rural (World Bank, 1995). Indeed, low yields make it difficult for rural populations to earn sufficient income for their subsistence. The instability of production can be explained by a combination of several factors such as constraints in access to technology and innovation, declining soil fertility and inefficient farming practices (Deressa et al, 2009). Technical support through regular monitoring by technical agents is an alternative to improve productivity (Yaï et al, 2020). Human capital improves worker efficiency through technical support. Contacts with the extension service constitute a component of human capital through the learning mechanism, best suited to uneducated or less educated farming populations. It helps train producers on Good Agricultural Practices (GAPs) (Yaï et al, 2020). The link between productivity and human capital development has been the subject of several economic theories (Jorgensen and Griliches 1967; Bonjean and Arcand 1999; Kabore, 2010).

Education reduces technical and allocative inefficiency in production. Educated people are more receptive to new technologies or farming techniques (Kabore, 2010). In addition, they can appreciate the appropriateness of the timing of the adoption of new technologies (Weier, 1999). This information points to the importance of training in improving the yield, income and welfare of farm households. Côte d'Ivoire became the world's leading cashew nut producer ahead of India in 2015. This crop represents an important source of income for the population and an improvement in their living conditions. However, the yield is low and in the range of 3.5 to 5 kg/tree compared to that of other countries such as Brazil, India and Tanzania, with yields of 10 to 15 kg/tree (Mouria et al, 1997). The Ivorian government has put in place voluntary strategies for the modernization and transformation of agriculture through the transfer of cultural and technical innovations in rural areas. Thus, since 2014, ANADER has trained nearly 45,000 cashew producers in GAP out of an estimated 450,420 producers, with an overall adoption rate of 10% (ENSEA-ACG/ PPCA, 2019/2020). In order to improve agricultural productivity and preserve the environment, changes in farming practices that are more cost-effective and environmentally friendly are promoted. These modifications consist in the adoption of best practices called Good Agricultural Practices (GAPs) predefined by technicians. GAPs are defined as practices that meet current needs, improve livelihoods, and preserve the environment in a sustainable manner (Nacro et al, 2010). Specifically, the notion of GAPs refers to sustainable management of soil fertility, integrated pest and disease management, and the control of crop management practices (FAO; 2005). However, it was noted the adoption of GAPs by cashew producers is low, with adoption rates ranging from 10% to 20% (ENSEA-ACG/ PPCA, 2019/2020). The objective is to assess the impact of GAPs training on the yield and income of Ivorian producer households. The trial is structured as follows:

Methodology

The data are from a sample survey conducted by the Cotton and Cashew Board in 2017. The sample size is 319 producers made up of 106 producers from four departments of the Gbêkê region, and 213 producers from three departments in Poro region. Our sample is composed of 95.3% men and 4.7% women; 44.8% of the producers in the sample have not received GAPs training, while the remaining 55.2% have had the training. Additionally, the sample was composed of 34.8% of producers who had observed the presence of pests and diseases and 65.2% who had healthy orchards. The interviews focused on the identification of the producer, farm, expenses and the GAPs training received. They also focused on yield, health and education expenses and the characteristics of the producer's housing and equipment, community participation and retrospective expenses during the last twelve (12) months preceding the survey.

Model specification

The methodology we used in this study is the matching approach introduced by Rosenbaum and Rubin (1983). The idea of the matching method is to associate to each treated individual (here, training received) an untreated individual (training not received) whose characteristics are identical to those of the treated individual (Brodaty et al, 2007). Based on a few assumptions, we can determine the average effect of the treatment in the population of treated individuals (ATT) corresponding here to an increase in the income of producers who received the training.

Let Ti = 1 for producers who have received GAP training, in this case the "adopters", and Ti = 0 for producers who have not received training. Yi represents the variable of interest in our study, the yield and income of producers. The treatment effect, here being an adopter, is equal to :

ℵ ü (1.1)

Where Yi1 is the variable of interest when the producer has received the treatment and Yi0 when the producer has not received the treatment.

However, it is impossible to study the same person in both treatment situations, so we must measure the average effect on the treated population (the adopters), which we noted as:

ü üü§üüü üü (1.2)

Here we want to estimate the average impact of the treatment on the treated, noted ATT (Average Treatment effect on the Treated). It is not possible for us to estimate E (Yi0| Ti = 1) and even if we know E (Yi0| Ti = 0) it is not possible to use it as a substitute.

Moreover, it is quite possible that the variables determining the treatment decision (being an adopter) also determine the variable of interest (income and return), hence the income and return of treated and untreated individuals are different, which would correspond to the selection bias (Caliendo and Kopeinig, 2008).

Thus, we can estimate ATT that provided that

üü§üüü ℵ §ß (1.3)

The conditional independence of the observable characteristics (Conditional Independence Assumption) is then assumed. From this assumption, the variable of interest must be independent of being treated (control group) by the variables X that describe the individual. This assumption implies that the selection is based solely on the observed characteristics X and that all variables that simultaneously influence the treatment and observable variables of the producers (Caliendo and Kopeinig, 2008). Furthermore, the satisfaction of the CIA hypothesis is the condition for the matching to be done by propensity scores. This hypothesis is written (Bonnard C., 2013) :

üü=ü§üℵüüü (1.4)

Or üüü§üü§ ℵ = ü (1.5)

Under this hypothesis we can write:

üü§üüü§üü§ü§üℵ§=§ üüü (1.6)

The estimation will consist of using the information we have on the untreated individuals to construct a counterfactual for each treated individual, i.e. an estimate of what the situation would have been if he or she had not been treated (Brodaty et al, 2007). However, this assumption implies the inclusion of a large number of X variables, so matching may be difficult (Bonnard, 2013). An alternative method to deal with the X vector dimension problem was proposed by Rosenbaum and Rubin (1983). It is the propensity score matching method corresponding to the probability that a person of given characteristics X is exposed to the treatment. They showed that the property of independence in relation to the observed characteristics X implies that of independence from the variable of treatment indicating the probability of treatment, or propensity score to be treated (Brodaty et al, 2007). Note : üü ℵ§ ü . (1.7)

We have: (1.8) üü=üü§ℵ

The matching is then written:

ℵ$_{üüü}$ ü$_{ü ü ü}$ üüüüüü ü ü (1.9)

A second assumption to follow in the matching method is the common support. It requires each of the treated individuals, untreated individuals whose score has values close to the score of the treated individuals. In other words, the density of the score of the untreated individuals must not be zero in the vicinity of the score values of the treated individual under consideration (Fougère, 2010). It ensures that for each treated unit, there are control units relying on the same observed variables X (Bonnard, 2013). We thus have:

ü§ℵü ü (1.10)

Choice and description of variables

The outcome variables are orchard yield and producer income.

Sex: this is a binary variable, representing the gender of the producer. It takes the value 1 when it is a man and 0 if it is a woman.

Age: represents the age of the producer and takes the value 0 when the producer is less than 36 years old and 1 when he is 36 years old or more.

Niv_instruc : is the level of education of the producer, it is a multinomial variable taking the value 0 for the not educated, 1 for the primary level, 2 for the secondary level.

Size_men: corresponding to the size of the farmer's household, is a continuous variable.

Member_asso: represents the membership of an agricultural production organization taking the values 1 if yes and 0 if no.

Nbre_enft : represents the number of children in the household. It is a continuous variable.

Sup: is the area of cashew orchards and is a continuous variable.

Typ_MO: corresponds to the type of labor available to the household. It can be 0 if it is "contractual", 1 if it is "family" and 2 when it is "help".

Typ_semen: represents the type of seed used for cashew cultivation in the orchard. It takes the value 0 when it is improved plant material and 1 when it is normal seeds.

Nbre_cham : corresponds to the number of cashew orchard that the household owns. It takes the value 1 when the household has only one orchard and 2 when it has two or more orchards.

Agever: represents the age of the cashew orchard and is a continuous variable.

Sitmat: is the marital status of the producer, a binary variable taking the value 1 for "married" and 0 for "not married".

Existmalrav : it is a binary variable representing the presence of diseases and pests in the orchard. It takes the value 1 if yes and 0 if no.

Yield: this is the yield of the orchard obtained from the total production divided by the area expressed in hectare, it is continuous.

The treatment variable is:

GAP: corresponds to whether or not the producer has received GAP training. It is a binary variable that takes the value 1 if the producer has received training and 0 if not for the whole sample and for the subsets of producers who have their orchards infected or not.

Table 1 : Descriptive statistics

In %	**BPA training received**	
	No	Yes
	Individual characteristics of the operator	
Sex		
Man	54,74	45,21
Wife	68,75	31,25
Age		
-36 years	48,48	51,52
+36 years	57,31	42,69
Niv_instruc		
Pas_instru	54,85	45,15
Primary	54,76	45,24
Secondary	62,07	37,93
Taille_mén	11,12	10,63
membr_asso		
Yes	56,78	43,22
Not	54,73	45,27
Exist_mal		
Yes	40,54	59,46
Not	63,46	36,54
Sitmat		
Married	54,92	45,08
Unmarried	62,50	37,50
	Characteristics of the holding	
U	3,65	3,42
Typ_MO		
Contractu	52,25	47,75
Family	56,77	43,23
Help	62,50	37,50
Typ_semen		
Mat_vé_am	46,67	53,33
Normal	56,40	43,60
Nbre_cham		
1	58,62	41,38
2	42,11	57,89
Agever	11,31	13,22
Makes	0,308	0,431

Source: Author from survey data (2017)

Results and discussions

Table 1 in the appendix presents the descriptive statistics of our different variables. Our descriptive statistics on the women in our sample show that only 31.25% of them have received GAP training (Table 1). Majority of producers under 36 years of age have received training (51.52%). Among the non-educated producers, 45.15% have received GAP training (Table 1). In addition, 43.22% of producers who are members of a farmer organization have received GAP training compared to 45.27% who are not members of a farmer association. Similarly, fewer producers with uninfected fields received training (36.54% versus 59.46%). Table 1 also shows that 45.08% of the sample of married farmers received training, compared to 37.50% of those who are not married. Regarding the characteristics of the farm, producers who received GAP training have on average smaller farms than those who did not receive training (3.42 ha versus 3.65 ha). Finally, the average yield is greater for producers who have received training (0.431 tons) than for producers who have not received training (0.308 tons) (Table 1).

Effect of GAP training on performance

The naïve estimators are positive and insignificant for the whole sample and the subgroup with no infected orchards (Table 2). After matching, the results of the estimates show a significant yield gain for the producers treated whatever the sample considered. Indeed, the nearest neighbor result shows an average treatment effect of 7.7%, the kernel result is similar with a rate of 3%. This implies that producers who received GAP training have 7.7% more yield than they would have had if they had not received training. The radius, core and stratification results are consistent with the nearest neighbor result and thus corroborate and add robustness to our results. This result also confirms our first hypothesis that GAP training increases orchard productivity (Atangana et al, 2012) and is therefore beneficial for the sustainability of cashew cultivation.

Table 2: Results by matching method (yield)

		nearest neighbor	Radius (0,1)	kernel	Stratification
All producers	naïve estimator	0,117			
	That	0,077**	0,003	0,030*	0,030***
	common Support	312	312	312	312
Producers who do not have their orchards infected	naïve estimator	0,015			
	That	0,049*	0,012	0,025*	0,022
	common Support	203	203	203	203
Producers with infected orchards	naïve estimator	0,009			
	That	0,052***	0,022	0,058**	0,069***
	common Support	107	107	107	107

Note : *** significant a 1%, ** significant a 5%, * significant a 10%

It should be noted that the result of the nearest neighbor method for producers with the presence of diseases and pests in their orchards is positive and greater than that of producers with no disease in their orchards. That is to say 5.2% against 4.9% significant respectively at 1% and 10%. This means that, firstly, the training allows the infected beneficiaries to achieve 5.2% more yield than they would have achieved without being trained, which shows us the impact of training on the management of diseases and pests. Second, for uninfected growers, the training allowed growers to achieve 4.9% more yield than they would have if they had not been trained. Although their orchards were not infected, they took advantage of the training modules to improve their yield.

Effect of GAP training on household income

For the estimation of the impact of GAP training on income, the results are shown in Table 3 below. The results show that the naive estimators are insignificant for all samples. The matching results show a significant income gain for producers regardless of the sample considered. For all producers, the nearest neighbor result is 7.6% significant at the 10% level while the radius and kernel and stratification results are 7%, 13.4% and 12.4% significant at the 10%, 1% and 5% levels respectively. These results mean that we have an average treatment effect of 7.6% and therefore an increase in income of 7.6% compared to those who did not receive training. This result validates our hypothesis that GAP training has a positive impact on producers' income (Bocoum et al, 2013). Furthermore, the income gain due to GAP training is much higher for growers who do not have diseases and pests in their orchards. On the other hand, for growers with diseases in their orchards, the income gain is less significant compared to those who have their orchards healthy. This means that the training allowed producers with infected orchards to earn more than 19.5% of the income they would have earned if they had not received training. The training therefore allowed an income of 19.5% more. For producers with uninfected orchards, they earned 32.5% more income than they would have if they had not been trained. The other non-disease related modules of the training allowed them to improve their income. In contrast to the yield here, disease mitigates producers' earnings, which can be justified by the costs of dealing with disease, which reduce revenue (Houngbo, 2012).

Table 3: Results by matching method (Income)

		nearest neighbor	Raduis (0,1)	kernel	Stratification
All producers	naïve estimator	0,117			
	That	0,076*	0,070*	0,134***	0,124**
	common Support	315	315	315	315
Producers who do not have their orchards infected	naïve estimator	0,176			
	That	0,325**	0,122	0,192***	0,207***
	common Support	200	200	200	200
Producers with infected orchards	naïve estimator	0,009			
	That	0,195**	0,125**	0,094	0,072
	common Support	101	101	101	101

Note: *** significant a 1%, ** significant a 5%, * significant a 10%

Conclusion

The study evaluated the impact of GAP training on orchard yields and producers' income based on the hypothesis that training improves productivity and income. The results revealed a significant yield gain for all producers. This gain is quite significant for producers with infected orchards. This means that training allowed producers with infected orchards to achieve 5.2% more yield than they would have achieved without being trained. It was also found that GAP training had a significant positive impact on income. It appears that for growers who did not have their orchards infected by the disease, the training had a greater positive impact on their income. This means that the other non-disease related modules of the training improved their income. In contrast to yield, disease mitigates producers' earnings, which is justified by the costs of dealing with disease, which reduces revenue.

Thus, in view of these conclusions, we make a few recommendations.

To the public authorities:

-Intensify GAP training.

-Mobilize incentives for the adoption of GAP.

To producers:

-Participate in GAP training.

-Implement GAP.

Acknowledgements

This article was only possible thanks to the combined efforts of several people to whom we would like to express our deep gratitude. Our gratitude goes to Professor BALLO Zié and Professor ZAHONOGO Pam for having accepted to direct this work. We express our deepest gratitude to Dr. OUATTARA Mariam and the Council for the Regulation, Monitoring and Development of the Cotton and Cashew Nut sectors (CCA), as well as to Professor SORO Sibiri for their precious support. Thanks also to the Cashew Research and Development Network in Africa (REDAA).

References

Araujo, C., Bonjean, C. A., Arcand, J. L. (1999), "Human Capital, Agricultural Productivity, and Women's Work: Latent Variables and Separability in Household Models" In Working Paper 99-12 CERDI. FSEG, University of Clermont I, U. Auvergne.

Atangana, J., Fomena, A., Tamesse, J. L., Fondjo, E. (2012), "Agricultural Practices and Epidemiology of Malaria in the Sudano-Sahelian Zone of Cameroon," Bulletin of the Society of Exotic Pathology, 105(1), 23-29.

Becker, G. S. (1964), "Human Capital, A theoretical and Empirical Analysis" Colombia University, Press for the National Bureau of Economic Research, New York.

Bocoum, I., Issa, A., Yahaya, S., Zezza, A. (2013), "Livestock and living conditions of households in Niger" INS-Niger.

Bonnard, C. (2013), "Incentives for innovation in the private sector" Recherches économiques de Louvain- Louvain economicreview 79(2), 45-81.

Brodaty, T., Crépon, B., Fougère, D. (2007), " Microeconometric methods of impact evaluation and their applications to active employment policies" Economie et prévision, (177), 91-118.

Caliendo, M., Kopeinig, S. (2008), "Some pratical guidance for the implementation of propensity score matching" Journal of economic survey, 22(1), 31-72.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., Yesuf, M. (2009), " Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia" Global environmental change, 19(2), 248-255.

Ecole Nationale Supérieure de Statistiques et d'Economie Appliquée (ENSEA), African Consulants Group (ACG). (2020), "Study on the baseline situation and monitoring of the impact of the PPCA" Study Report, 145.

Food and Agriculture Organisation (FAO), (2004), "FAO Expert Consultation on Food Safety: Science and Ethics" FAO: Rome, Italy, 13.

Food and Agriculture Organisation (FAO), (2005), "The State of Food and Agriculture. Agricultural Trade and Poverty: Can Trade Serve the Poor? FAO, Rome, 21.

Fougère, D. (2010), "Les méthodes économétriques d'évaluation" Revue française des affaires sociales 1(1-2), 105-128.

Kabore, T. (2010), "The Impact of Human Capital on Agricultural Productivity in Burkina Faso. 138-2016-1934.

Mouria, A., Ouazzani, T., Douira, A., Benkirane, A., Mlaiki, R., Yachioui, M. (1997), "Antagonisme in vitro de Trichodermaspp. Vis-à-vis pyriculariose oryzae" Al awamia, 96: 9-17.

Nacro, S., Ouedrago, S., Traore, K., Sankara, E., Kabore, C., Ouattara, B. (2010), "Comparative effect of peasant practices and good agricultural practices in soil fertility management on soil properties and crop yields in the Sudanese zone of Burkina Faso" Int. J. Biol. Chem. Sci. 4(4): 1044-1055.

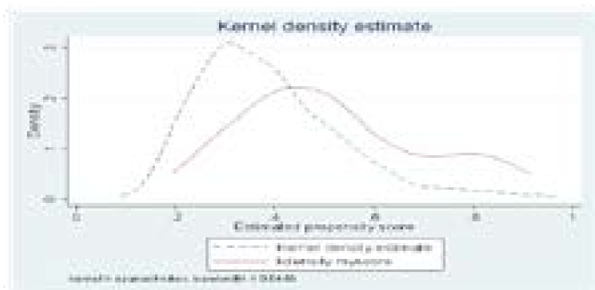
United Nations Development Programme (UNDP). (2019), "Beyond Incomes, Averages and the Present Time: Inequalities in Human Development in theTwenty-first Century" Human Development Report.

Rosenbaum, P. R., Rubin, D. B. (1983), "the central role of the propensity score in observational studies for causal effects" Biometrika, 70(1), 41-55.

Yaï, D. E., Yabi, J. A., Biaou, G., Floquet, A., Degla, P. (2020), "Agricultural Productivity and Food Security of Agricultural Households in Benin: An Orthodox Approach" International Journal of Innovation and Applied Studies, 29(4), 1199-1215.

ANNEXES

Propensity score of all producers treated



ASSESSMENT OF STRATEGIES FOR IMPROVEMENT OF CASHEW NUT PRODUCTION IN OGBOMOSO METROPOLIS, OYO STATE, NIGERIA

Ewetola, E. A., Owoade, F. M., Babajide, P. A., Oyediran, G. O. and Olaniyi, J.O.

Department of Crop Production and Soil Science
Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
Corresponding author e-mail: eaewetola@lautech.edu.ng

Abstract

The diverse uses of cashew nut across industries and households have spurred global demand, unlocking opportunities for Nigerian farmers. However, high post-harvest losses have caused huge income losses to cashew investors. This study assessed the strategies for improvement of cashew production in Ogbomoso metropolis, Oyo State, Nigeria. The research work described the personal characteristics of cashew nuts producers, ascertained cashew nuts production strategies and investigated the constraints to production of quality cashew nuts in the area. The study collected data from 118 respondents (cashew farmers') using structured interview schedule. The study found out that the mean age of the respondents was 47 years. Among the production strategies used by respondents for cashew quality improvement include provision of: basic incentives to the farmers before and after cashew production season (74.6%), end of season gift for outstanding performance among the farmers in terms of cashew output (70.3%) and improved seeds to the farmers for replacement (66.1%). The most significant constraints to cashew quality production among cashew farmers were climate change and pests and diseases. Pearson Correlation analysis revealed that selected personal characteristics such as age ($r = 0.264$; $p<0.002$), years spent in school ($r = 0.536$; $p<0.000$) and farming experience ($r = 0.824$; $p<0.001$) exhibited significant relationship with the effectiveness of identified cashew production strategies. The study concluded that cashew farmers utilized several strategies for the improvement of cashew production. It also recommended that adequate and relevant training on cashew nut production and other identified strategies should be reinforced by stakeholders in the industries.

Keywords: Cashew nut, Strategies, Quality, Ogbomoso Metropolis, Nigeria

INTRODUCTION

Cashew is one of the important plantation commodities to be developed because it is one of the country's foreign exchange earners. Despite the promising potentials of cashew in Nigeria, farmers are said to be experiencing many constraints in cashew production, processing and marketing (Oluyole et al., 2015). These constraints as well as changing climate have resulted in a drop in the level of cashew production in Nigeria in recent years (Bello et al., 2016).

An increasing awareness of the economic potential of cashew kernels in the global market has further led to the influx of farmers, government and non-government organizations (NGO) into the business of cashew production, with the total area of land planted to cashew reaching about 320,000 hectares, and about 256,000 metric tons annual nut production in 2003 (Aliyu, 2004). However, cashew production in Nigeria continues to be limited by low yield, variable nut yield and quality. It has been observed that most Nigerian cashew farmers do not use fertilizer and thus the nutrients being mined by the plants are not replenished. The likely causes of low quality in production of cashew amongst others may be; unimproved planting materials, overcrowding and interlocking, poor maintenance /abandoned, pest and disease infestations, low plant population and low soil fertility.

The agricultural sector has been recognized as key to driving Nigeria's economic diversification plan. Although there are no stand-alone regulations on cashew production and processing in Nigeria, relevant regulatory bodies such as the Federal Ministry of Agriculture and the Nigerian Export Promotion Council (NEPC) have initiated approaches to reposition the cashew value chain for success (This day, (2020).

The diverse uses of cashew across industries and households have spurred global demand, unlocking opportunities for Nigerian farmers and investors. Cashew is produced for various purposes including medicinal, industrial and household uses. However, high post-harvest losses have caused huge income losses to cashew farmers and investors. Consequently, the research work is necessitated to unlock the potentials of Nigeria cashew farmers through assessing the strategies for improvement of quality cashew nut production which can attract better income for farmers.

Objective of the Study

The study assessed the strategies for improvement of cashew production in Ogbomoso metropolis, Oyo State, Nigeria.

Specifically, the study:

i. described the personal characteristics of cashew nuts producers in the study area;

ii. ascertained cashew nuts production strategies in the area:

iii. identified the effectiveness of the strategies for cashew quality improvement in the study area and investigated the constraints to cashew nuts quality production in the area.

Research Questions and Hypothesis

The study provided answers to the following research questions:

i. what are the personal characteristics of cashew nuts producers in the study area?

ii. what are cashew nuts production strategies in the area?

iii. what is the effectiveness of those strategies for cashew quality improvement in the study area? and

iv. what are the constraints associated with cashew nuts quality production in the area?

Hypothesis of the study

H0: There is no significant relationship between selected personal characteristics of respondents and effectiveness of strategies for improvement of cashew nut production.

METHODOLOGY

3 I Study Area

The study was carried out in Ogbomoso metropolis of Oyo State, Nigeria. Ogbomosho is a city in Oyo State, south-western Nigeria, on the A1 highway. It was founded in the mid-17th century. The population was approximately 245,000 in 2006 census. The majority of the people are members of the Yoruba ethnic group. Yams, cassava, cashew, mango, maize, and tobacco are some of the notable agricultural products of the region (Reporters Emporium, 2021). According to Akinfenwa (2019) as reported in 'The Guardian' that Ogbomoso is the home of best quality cashew, which has endeared the heart of importing countries. Ogbomoso has the best soil and climate for cashew production in Nigeria and also produces the best quality cashew nuts. Cashews from this area have far better commercial value than those from other areas in the country.

Research Design and Procedures

3.2 Population of the Study

The population of the study comprises of all cashew nuts producers in the area.

3.3Sampling Procedure and Sample Size

The list of registered cashew nut producers was obtained from their respective associations in each of the local governments. The list has 394 cashew nut producers in Ogbomoso metropolis. Random selection of 30% of the cashew nuts producers were used for the study. This gives a total sample size of 118 respondents.

Data Collection and Analysis Procedures: Sampling and Instrumentation

3.4 Method of Data Collection

Data for this study was collected through primary survey using interview schedule. The interview scheduled was designed in line with the objective of this study.

3.5 Reliability and Validity of Research Instrument

The interview schedule was pre-tested among cashew nut producers in Osun State. The instrument was validated by the professionals/researchers in the field of Agricultural Extension and related social sciences. The reliability of the instrument was ascertained after test and re-test method using split-half method in order to obtain r-value. This was done to enhance the quality of the instrument.

3.6 Measurement of Variables

The study measured both dependent and independent variables. The dependent variable was the effectiveness of strategies for improvement of cashew nut production. This was measured by listing out strategies for improvement of cashew nut productions which include: provision of improved seed to the farmers, fortnight assurance visitation to the farmer's field, provision of basic incentives to the farmers, advanced payment/funding prior to harvesting, fortnight stakeholders meeting before and after cashew production season, proper record keeping of the production capability of farmers, provision of end of season gift to compensate outstanding performance among the farmers in terms of cashew output and fortnight provision of training to farmers on quality improvement before and after cashew production season. . Responses to these were measured on a three points rating scale of Very Effective (2), Effective (1), and Not Effective (0). Weighted mean score was used to rank the effectiveness of strategies for improvement of cashew nut production. The independent variables were also measured accordingly.

3.8 Data Analysis

Both descriptive and inferential statistical tools were used for data analysis. Frequency distributions, percentages and mean were used to describe the data. Descriptive statistics was used for all the objectives, while Pearson Product Moment Correlation (PPMC) inferential tool was used to test the formulated hypothesis of the study.

DISCUSSION OF FINDINGS

Personal characteristics of the respondents

Age distribution revealed that 40.7% of the respondents were between 41 – 50 years of age, 27.4% of the respondents were between 51 – 60 years of age, 24.2% of the respondents were 31 – 40 years of age, while 7.7% of the respondents were above 60 years of age. The mean age of the respondents was revealed to be 47 years. This result indicated that the respondents in the study area were in their middle and active age and this implies that the respondents are still agile to seek new strategies for improvement of cashew production so as to attain profit.

Sex: The results on sex revealed that majority (72.2%) of the respondents were male while 27.8% of the respondents were female. The result indicates that majority of the respondents in the study area were male, as male dominated the cashew production in the study area. This implies that men could be ready and willing to undergo the innovations and strategies towards improving the cashew productions in the study area.

Marital status distribution revealed that 95.8% of the respondents were married, while 4.2% of the respondents were not yet married respectively. This implied that majority of the respondents in the study area were married.

Religion: The result revealed that 52.5% of the respondents were Muslim, while 47.5% of the respondents were Christian.

Years spent in school: The result revealed that about 38.1% of the respondents spent above 7 – 12 years in school, 32.2% of the respondents spent 1 – 6 years in school, 22.9% of the respondents spent more than 12 years in school, while 6.8% of the cashew producers didn't go to school at all. The mean years spent in school was 10 years. This indicates that majority of the farmers in the study area were literate. This implies that the farmers' education level will influence their strategies, thereby improve their readiness and ability to comprehend the new idea/strategies so as to increase their cashew production.

Social Organization membership: The result revealed that majority (97.5%) of the cashew producers were member of social organization, while only (2.5%) of the respondents were not member of social organization This indicates that barely all the respondents in the study area were members of social organization. This implies that cashew farmers that belong to social organization will be more exposed which can offer skills to enhance the production of quality cashew nut in the study area.

Membership status: Table 1 showed that 92.2% of the cashew producing farmers filled up the position of membership in the association, while only (7.8%) of the respondents were executives in the association.

Farming experience: The result in Table 1 revealed that most (59.4%) of the cashew producing farmers had not more than 10 years of cashew production experience, 22% had 11 – 20 years of cashew production experience, 16.9% had 21 – 30 years of cashew production experience, while 1.7% of the cashew farmers had more than 30 years of production experience. The mean year of production experience among the cashew farmers was 12.4 years. This implies that cashew farmers' production experience predisposes cashew farmers to acquisition of skills and strategies towards production of cashew, which will increase their cashew farmers' profitability.

Mode of transaction: The result in Table 1 further revealed that majority (84.7%) of the cashew nuts farmers transacted their cashew nuts through produce buyers in town, while 15.3% of the cashew nuts farmers transacted their cashew nuts through exporter out of the town. This implies that the cashew nut farmers small scale marketers transacted their produce to the large scale co-produce buyer.

Table 1 Distribution of respondents according to their personal characteristics.

Socio-economic characteristics	**Frequency**	**Percentage**	**Mean**
Age (years)			
≤30	6	4.8	43.95
31 – 40	38	32.4	
41 – 50	46	40.4	
51 – 60	25	20.0	
>60	3	2.4	
Sex			
Male	106	89.8	
Female	12	4.2	
Marital status			
Married	113	95.8	
Unmarried	5	4.2	
Religion			
Christianity	56	47.5	
Islam	62	52.5	
Years spent in school			
No formal education	8	6.8	10
1 – 6	38	32.2	
7 – 12	45	38.1	
Above 12	27	22.9	
Social Organization membership			

Yes	115	97.5	
No	3	2.5	
Membership status			
Executive	8	7.8	
Member	110	92.2	
Farming experience (years)			
≤10	70	59.4	12.4
11 – 20	26	22.0	
21 – 30	20	16.9	
Above 30	2	1.7	
Mode of transaction			
Produce buyers in town	100	84.7	
Exporter out of town	18	15.3	
Total	118	100.00	

Source: Field Survey, 2022

Cashew production strategies used by the cashew farmers

Table 2 shows the distribution of respondents by cashew production strategies used by cashew farmers for cashew quality improvement in the study area. The result revealed that majority (83.1%) of the respondents used strategy of advanced payment/funding prior to harvesting, majority (80.5%) used strategy of fortnight stakeholders meeting before and after cashew production season, 74.6% used strategies of fortnight provision of training to the farmers, 74.6% used strategy of provision of basic incentives to the farmers on quality improvement before and after cashew production season, 70.3% used strategies of provision of end of season gift to compensate outstanding performance among the farmers in terms of cashew output, 66.1% used strategies of provision of improved seed to the farmers for replacement, 63.6% used strategies of proper record keeping of production capability of farmers/suppliers, 62.7% used strategies of fortnight assurance visitation to the farmers/farmers' field, for cashew improvement strategies respectively. This implies that the cashew farmers utilized several strategies towards the improvement of cashew production for cashew quality improvement, which would have positive effect on the quality and quantity of cashew nut production output, and thereby increase the incomes of the farmers from cashew production in the study area.

Table 2: Cashew production strategies used by cashew farmers in the study area

Cashew production strategies	***Frequency(Percentage)**
Provision of improved seed to the farmers	78(66.1)
Fortnight assurance visitation to the farmers	74(62.7)
Provision of basic incentives to the farmers	88(74.6)
Advanced payment/funding prior harvesting	98(83.1)
Fortnight stakeholders meeting	95(80.5)
Proper record keeping of production capability	75(63.6)
Provision of end of season gift for compensation	83(70.3)
Fortnight provision of training to the farmers	91(77.1)
Total	118(100.0)

Source: Field Survey, 2022

*Multiple response

Effectiveness of identified strategies for cashew nut quality improvement

Table 3 shows the distribution of respondents by their effectiveness level of identified strategies for cashew nut quality improvement in the study area. For this objective, the 3 rating scale of "very effective, effective, and not effective" were used, thereafter mean was computed and ranked accordingly in Table 3. The table shows that the strategies of fortnight provision of training to the farmers on quality improvement before and after cashew production season, proper record keeping of production capability of farmers/suppliers, and advanced payment/funding prior harvesting ranked first (1st) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 1.4 respectively, the strategy of fortnight stakeholders meeting before and after cashew marketing season ranked fourth (4th) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 1.3, strategy of provision of end of season gift to compensate outstanding performance among the farmers in terms of cashew output ranked fifth (5th) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 1.2, strategy of provision of basic incentives (chemicals, cutlass) to the farmers ranked sixth (6th) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 1.1, strategy of fortnight assurance visitation to the farmers/farmers' field ranked seventh (7th) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 0.9, while strategy of provision of improved seed to the farmers for replacement ranked eighth (8th) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 0.7. The result indicated that strategies of fortnight provision of training to the farmers on quality improvement before and after cashew marketing season, proper record keeping of production capability of farmers/suppliers, and advanced payment/funding prior harvesting ranked first (1st) as the level of identified strategies for cashew quality improvement, with weighted mean score (WMS) of 1.4 respectively. This implies that the cashew farmers' production strategies could facilitate the cashew quality improvement, thereby influenced their cashew production output.

Table 3: Effectiveness of identified strategies for cashew quality improvement

Cashew production strategies	Very Effective	Effective	Not Effective	WMS	Rank
Provision of improved seed to the farmers	6(5.1)	67(56.8)	45(38.1)	0.7	8th
Fortnight assurance visitation to the farmers	16(13.6)	73(61.9)	29(24.6)	0.9	7th
Provision of basic incentives to the farmers	24(20.3)	78(66.1)	16(13.6)	1.1	6th
Advanced payment/funding prior harvesting	54(45.8)	53(44.9)	11(9.3)	1.4	1st
Fortnight stakeholders meeting	48(40.7)	59(50.0)	11(9.3)	1.3	4th
Proper record keeping of production capability	55(46.6)	51(43.2)	12(10.2)	1.4	1st
Provision of end of season gift for compensation	49(41.5)	42(35.6)	27(22.9)	1.2	5th
Fortnight provision of training to the farmers	58(49.2)	51(43.2)	9(7.6)	1.4	1st

Source: Field Survey

Figures in parentheses are percentages

Constraints to cashew quality production among cashew farmers

Table 4 shows the distribution of respondents by constraints to cashew quality production among cashew farmers in the study area. Table 4 revealed that majority (80.5%) of the respondents indicated climate climatic (rainfall, temperature) as constraints to cashew quality production among cashew farmers, majority (76.3%) of the respondents indicatedpest and diseases, as the constraints to cashew quality production among cashew farmers, 66.9% of the respondents indicateddeforestation, as constraints to cashew quality production among cashew farmers, 57.6% of the respondents indicatedtheft, as constraints to cashew quality production among cashew farmers, 41.5% of the respondents indicatedurbanization, as constraints to cashew quality production among cashew farmers, while 36.4% of the respondents indicatedpoor harvesting method, as constraints to cashew quality production among cashew farmers . The result implies that farmers encountered different challenges in the production of quality cashew nut which can deteriorate the production of cashew nut, thus affecting the marketing value of the cashew nuts produce in the study area.

Table 4: Constraints to cashew quality production among cashew farmers

Constraints	*Frequency(Percentage)
Climatic change (rainfall, temperature)	95(80.5)
Deforestation (alternative use of tree)	79(66.9)
Urbanization	49(41.5)
Pests and diseases	90(76.3)
Poor harvesting method	43(36.4)
Theft	68(57.6)
Total	**118(100.0)**

Source: Field Survey, 2022

*Multiple responses

Test of Hypothesis

Significant relationship between selected personal characteristics of respondents and the effectiveness of identified cashew production strategies for cashew quality improvement

Pearson Product Moment Correlation (PPMC) analysis shows the relationship between selected personal characteristics and the effectiveness of identified cashew production strategies for cashew quality improvement. The result revealed that selected personal characteristics such as age ($r = 0.264^{**}$; $p<0.002$), years spent in school ($r = 0.536^{**}$; $p<0.000$), association membership (0.431^{*}; $p<0.002$), farming experience ($r = 0.824^{**}$; $p<0.001$) exhibited significant relationship with the effectiveness of identified cashew production strategies for cashew quality improvement. The result implies that all the selected personal characteristics have decisive influence with effectiveness of identified cashew production strategies for cashew quality improvement.

Table 5: Significant relationship between selected personal characteristics of respondents and the effectiveness of identified cashew production strategies for cashew quality improvement

Personal characteristics	Correlation coefficient (r)	p-value	Decision	Remark
Age	0.264**	0.002	S	Reject Ho
Years spent in school	0.536*	0.000	S	Reject Ho
Association membership	0.431**	0.002	S	Reject Ho
Farming experience	0.824**	0.001	S	Reject Ho

Source: Data Analysis, 2022

*: correlation is significant at 0.01 level

**: correlation is significant at 0.05 level

Conclusion

Based on the research findings, the following conclusions were made:

i. Cashew farmers utilized several strategies towards the improvement of cashew production for cashew quality improvement, which would have desirable influence on the quality and quantity of cashew nut production output, and thereby increase the income of the farmers from cashew production in the study area.

ii. The study identified proper record keeping of production capability; fortnight provision of training to the cashew farmers; advanced payment/funding prior harvesting as the best effectiveness strategies for cashew nut quality improvement in the study area.

iii. Farmers encountered different constraints in the production of quality cashew nut such as climatic change (rainfall, temperature); deforestation (alternative use of tree); urbanization; pests and diseases; poor harvesting method and theft.

Recommendations

Based on the findings, the study recommended that adequate and relevant trainings on quality improvement of cashew nut production and other identified strategies should be reinforced by stakeholders of cashew farming to improve the quality of cashew nut production in the area.

Acknowledgements

The authors express their gratitude to the Cashew Starlink Global and Ideal Research Grant for the financial support given through grant. We also thank Professor I. A. Emiola, Department of Animal Biotechnology and Nutrition, LAUTECH, Ogbomoso, Nigeria.

Reference

Akinfenwa, G. (2019). Ogbomoso takes front seat in cashew cultivation https://guardian.ng/features/ogbomoso-takes-front-seat-in-cashew-cultivation/ Accessed on 15 February, 2022

Aliyu O. M (2004). Cashew Industry in Nigeria: Production and Processing. A paper presented at the 1st Regional Cashew Competitiveness Seminar– Africa Region, organized by Techno Serve

Bello O. D., Akponikpe, P. B., Ahotou, E. L., Saidou, A., Ezin A. V., Kpadonou, G. E., Balogun I., Aho, N., (2016). Trend analysis of climate change and its impacts on cashew nut production in Benin. Octa Journal of Environmental Research 4:3

Oluyole, K. A., Yahaya, A. T., Uwagboe, E. O., Mokwunye, I. U., Agbeniyi, S. O., Orisajo, S. B., Otunoye, A. H., Ndagi, I., Shittu, T. R. and Aderolu, I. A. (2015).Constraints in cashew production among cashew farmers in South-western Nigeria. Journal of Basic and Applied Research International 17: 116 - 120.

Reporters, Emporium. Origin of Ogbomoso, Oyo state. Emporium Reporters. Retrieved 15 February, 2022

This day (2020). The Cashew Opportunity in Nigeria. Available online at https://www.thisdaylive.com/index.php/2020/12/27/the-cashew-opportunity-in-nigeria/Accessed on 15 February, 2022

CASHEW LEAF BLIGHT DISEASE IN GHANA: CAUSAL ORGANISMS, PATHOGENICITY AND CONTROL

Agyare S.,* Yahaya B., Amoako-Attah I., and Asare E. K.

Plant Pathology Division, Cocoa Research Institute of Ghana (CRIG)

*Corresponding Author: Dr. Solomon Agyare, Plant Pathology Division, Cocoa Research Institute of Ghana (CRIG), P. O. Box 8, Akim-Tafo, Ghana. Tel:+233(0)559908433; Email: pickoh@hotmail.com or Solomon.agyare@crig.org.gh

Abstract

Leaf and nut blight diseases of cashew limit productivity in the West African Sub-region. They arise from a complex of fungal pathogens and establishing the identity of candidate causal organism across defined ecologies could constitute a viable strategy to develop control options for the management of these diseases in the sub-region. In this study, cashew disease symptoms characterised by blight or spots on leaf and twig were collected from two farms each from Guinea savannah and Forest transitional and four farms from the Semi-deciduous zones for assessment. Leaf blight disease starts as minute irregular necrotic patches of brick red colour at the margins which enlarges and turns grey-silvery in colour covering major portions of the leaf surface. Symptoms of the nut blight also include necrotic brown patches covering the surfaces of the apples. Samples were cultured on different agar media and pure isolates of the pathogens were obtained by the single hyphal tip method. The pathogens were identified using morphological characteristics of the pure isolates. The isolates were used to inoculate healthy cashew leaves in the laboratory to confirm pathogenicity through Koch's postulates. Probable pathogens obtained were Pestalotia spp., Colletotrichum spp., and Lasiodiplodia spp. The efficacy of different fungicides containing copper and metalaxyl (60% copper + 6% metalaxyl; 35% copper hydroxide + 15% metalaxyl; 86% copper oxide and 77% copper hydroxide) as active ingredients were tested in the laboratory against Colletotrichum spp. and Pestalotia spp. The performance of the fungicides was generally comparable and had inhibitions ranging between 80-100%. Isolates of Pestalotia spp. were found to be more sensitive to the fungicides than that of Colletotrichum.

Keywords: Cashew leaf blight, *Pestalotia* spp., *Colletotrichum* spp., *Lasiodiplodia* spp. & *Pathogenicity*

1.0 Introduction

Leaf and nut blight diseases of cashew tend to reduce productivity in the West African Sub-region. In a study conducted in the Northern region of Ghana, Assuah et al. (2009) reported the severity of the cashew blight disease as high at the beginning of the year right into April. The disease severity remained high until October. The disease symptoms appear as minute irregular necrotic patches of brick red colour at the margins which enlarge and turn grey-silvery in colour covering major portions of the leaf surface. These necrotic patches may also spread to the apples. Previous studies in Ghana suggested that the disease arises from a complex of fungal pathogens involving Colletotrichum spp., Pestalotia spp., Lasiodiplodia spp., Aspergillus spp. and Penicillium spp. (Assuah et al., 2008). However, pathogenicity of the pathogens was not established. Establishing the identity of candidate causal organism across defined ecologies could constitute a viable strategy to develop control options for the management of the disease in the different ecological zones of Ghana. Consequently, focusing on establishing the identity of the causal organism through pathogenicity test and molecular identification process would be a step in the right direction as was reported in Tanzania (Sijaona et al., 2006; Menge and Shomari, 2016). In Tanzania, Cryptosporiopsis sp. was identified and reported as the main pathogen responsible for cashew leaf blight disease with symptoms such as angular lesions, dark tan with a dark reddish-brown margin of the leaves with lesion that frequently extends onto the apples, necrosis of epidermal tissue and chlorotic spots on both sides of the youngest tender leaves (Sijaona et al., 2006). However, Olunloyo and Esuruoso (1975) and Ngoh Dooh et al. (2021) reported Lasiodiplodia and Pestalotia as the cause of leaf blight diseases in Nigeria and Cameroon respectively.

Meanwhile, apart from using conventional fungicides to manage cashew diseases, one other strategy is to breed for disease resistant materials (Moreira et al., 2013). It is, thus, paramount to confirm the identity of the pathogen(s) responsible for cashew leaf blight diseases through pathogenicity test (Koch's postulates) and perhaps through a molecular identification process before proceeding to organize a challenged inoculation test or resistance level studies for cashew breeding programmes. Past works carried out in Ghana have suggested that the leaf blight disease of cashew may not be caused by a single organism, but a complex of several pathogens as indicated above. Consequently, it may be difficult to organize a challenged test in the future for cashew clones without being certain on the identity of the disease complex. However, it is also possible that the current study may identify a single pathogen responsible for the primary blight infection while the rest may simply be opportunistic pathogens taking advantage to cause secondary infections. This is common in some fungal diseases such as Botrytis cinerea which may be the main cause of infection of strawberry or raspberry fruit but other opportunistic pathogens such as Penicillium and Cladosporium may become prominent later on the fruit, causing secondary infections (Xu et al., 2012; Agyare et al., 2020).

After identification of the pathogens and confirmation of the pathogenic status of the candidate organisms from different cashew growing regions in Ghana, it is also crucial to investigate potential active ingredients of fungicides against the pathogens of interest for effective management against the diseases. This would help in safeguarding the cashew industry in Ghana. The main objectives of this study therefore were to confirm the causal organism(s) of the leaf blight disease of cashew in Ghana, establish the pathogenic status of the implicated pathogens and to test the efficacy of selected fungicides against the pathogens.

2.0 Materials and methods

2.1 Disease symptoms and sampling

Diseased samples were collected from cashew farms at Wa (Upper West Region, Guinea savannah), Bole (Savannah Region, Guinea savannah), Wenchi (Bono Region, Forest transitional), Techiman (Bono East Region, Forest transitional), Begoro (Eastern Region, Semi-deciduous), Aframase (Eastern Region, Semi-deciduous), Asesewa (Eastern Region, Semi-deciduous) and Gadza-Kpando (Volta Region, Semi-deciduous). The samples were collected from cashew disease symptoms characterized by blight or spots on leaf and twig.

2.2 Isolation of pathogens

Diseased tissues were cut into small pieces (5 x 5 mm), surface sterilised in 70 % ethanol for 30 seconds and rinsed three times in sterile distilled water (SDW). After blot drying on filter paper, the pieces were aseptically placed on different agar media and incubated at 25 °C for 3-5 days in the dark to allow fungal growth. The media used included chloramphenicol amended potato dextrose agar (PDA+), acidified malt extract agar (AMEA), yeast extract peptone dextrose agar (YEPD), YEPD-lactic acid agar (YEPD+LA) and YEPD sorbic acid hydrogen chloride agar (YEPD+HCl). They were prepared as follows:

Chloramphenicol potato dextrose agar (PDA+)

PDA (CMO 139, Oxoid Ltd) was prepared using the concentration recommended by the manufacturer (39 g/L). The medium prepared was amended with 500 µg/mL chloramphenicol and autoclaved at 121 °C for 15 mins. The medium was left on the bench to cool to 45-50 °C. About 30 mL of the molten medium was then poured into Petri dishes in a flow cabinet. The PDA+ plates were placed in sterile bags and kept in the fridge at 4 °C for use later.

Acidified Malt Extract Agar (AMEA)

Malt extract agar (Oxoid, Ltd) (25 g) was added to 500 mL distilled water in a media bottle according to the manufacturer's instructions. The bottle was shaken vigorously and autoclaved at 115 °C for 10 minutes. The media was left on the bench to cool for a while and kept in the water bath at 47 °C. A volume of 15 mL of 10 % (v/v) lactic acid was added and the media was poured immediately into Petri dishes.

Yeast Extract Peptone Dextrose (YEPD)-lactic acid agar (YEPD+LA)

Glucose (10 g) and bacteriological peptone (10 g) were added to distilled water (500 mL) in a media bottle. The bottle was shaken to ensure uniform distribution. Yeast extract (5 g) and agar (8 g) were then added to the solution and stirred by shaking the bottle to dissolve. The solution was then autoclaved at 121 °C for 15 minutes. The media was left on the bench to cool and then kept in a water bath at 47 °C in readiness for the addition of supplements before being poured into Petri dishes. A volume of15 mL of 10 % (v/v) lactic acid was added to the molten YEPD solution and mixed gently, avoiding bubbles. The molten media was immediately poured into Petri dishes.

YEPD- sorbic acid HCl agar (YEPD+HCl)

YEPD solution was prepared following previously explained procedure. A volume of 10 mL of 0.01M sorbic acid was added to the prepared YEPD solution before autoclaving at 121 °C for 15 minutes. The molten media was allowed to cool after autoclaving and kept in the water bath at 47 °C. A volume of 7 mL of 2M HCl was added to the molten media in a fume chamber. The molten YEPD agar was then poured immediately into Petri dishes

2.3 Purification and identification of pathogens

To obtain pure cultures of the fungal isolates, mycelial colony growing on the agar plates were sub-cultured twice onto the same antibiotic amended agar medium using single hyphal tip method. Culture morphology and microscopic characteristics of pure cultures were used to identify the isolates with the aid of identification manuals (Mathur and Kongsdale, 2003; Humber, 2005; Kirk et al., 2008).

2.4 Inoculation of cashew leaves to confirm the disease (Koch's Postulates)

Healthy matured leaves detached from cashew trees were washed with mild soap (Cussons Morning Fresh dish washing liquid soap) under running water and rinsed with SDW twice. Four 10 mm inoculation plugs from advancing margins of candidate isolates were used to inoculate the abaxial surface of the leaves under aseptic conditions. Leaves inoculated with sterile PDA plugs served as controls. The leaves were arranged in a completely randomised design (CRD) with four replications inside an aluminium tray lined with moist plastic foam (Figure 1).

Figure 1: A set up of cashew leaves inoculated with mycelial plugs of different cashew leaf blight pathogens in an aluminum tray lined with moist plastic foam. The beakers containing water provided the high relative humidity condition for infection.

Beakers of SDW were placed inside the trays, covered, and sealed to maintain high humidity. The trays were kept on a laboratory bench under ambient conditions (25 ± 2 °C) and examined after 7 days for infection. Symptoms and signs of the cashew blight disease on the inoculated leaves were compared with those from the field. The test isolates were re-isolated from the infected leaves and found to be morphologically identical to the original isolates inoculated thereby completing Koch's postulates. Pictures of the infected leaves were taken using digital camera (Samsung Galaxy A5 mobile phone). The entire experiment was repeated.

2.5 Growing of isolates on different prepared media

Different growth media prepared (i.e., PDA+, AMEA, YEPD+LA & YEPD+HCl) were used to assess optimal growth of some selected cashew leaf blight isolates. The plates were inoculated with 5 mm plugs taken from the edge of pure cultures of Pestalotia spp., Lasiodiplodia spp. and Colletotrichum spp. There were three replicated plates for each treatment per pathogen and incubated at 25 ± 2 °C for 7 days. Colony diameters were recorded each day and the mean diameters determined after the incubation period.

2.6 Screening of fungicides against cashew leaf blight pathogens

Four copper and metalaxyl-based fungicides: 60 % copper (1) oxide + 6 % metalaxyl; 35 % copper hydroxide + 15 % metalaxyl; 86 % copper (I) oxide and 77 % copper hydroxide were tested at their manufacturer's rate against isolates of Pestalotia and Colletotrichum species using the amended-agar plate test method. A 0.34g each of the copper + metalaxyl fungicide and 0.5 g of each of the sole copper fungicides were separately dissolved in 100 mL molten PDA medium. Approximately 20 mL of the amended PDA was poured into 9 cm Petri dishes and left to set. The plates were inoculated with 5 mm disc plugs taken from the edge of pure cultures of Pestalotia spp. and Colletotrichum spp. Non-amended plates were similarly inoculated to serve as control. There were three replicated plates for each treatment per pathogen and incubated at 25 ± 2 °C for 7 days. Colony diameters were recorded each day and percentage inhibition (PI) of mycelial growth was calculated as: $PI = (C-T)/C \times 100$ where PI = Percentage Inhibition of Radial Growth; C = average radial growth in control plates; T = average radial growth in test plates

2.7 Statistical analysis

The differences between the isolate diameters of the different amended growth media and fungicide treatments were compared and analysed using using ANOVA (GenStat for Windows version 9.2 and SigmaPlot 14.0). A statistical value of 0.05 or less was considered significant in all the ANOVA tests conducted.

3.0 Results

3.1 Sampling location, field observation and disease symptoms

Disease symptoms characterized by blight or spots on leaf, twigs and nut samples were collected from cashew growing areas as indicated in Table 1.

Table 1: Disease sampling locations in different agro ecological zones of Ghana.

Sampling location	Region in Ghana	Ecological zone	Global Positioning System (GPS)
Bole	Savannah	Guinea savannah	Lat: 9° 01' 60.00" N & Lon: -2° 28' 59.99" W
Wa	Upper West	Guinea savannah	Lat: 10°3'36.2664"N & Lon: 2° 30' 35.6076" W
Wenchi	Bono	Forest transitional	Lat: 7° 34' 22.79" N & Lon: -1° 55' 26.99" W
Techiman	Bono East	Forest transitional	Lat: 7° 35' 10.21" N & Lon: -1° 56' 28.93" W
Begoro	Eastern	Semi-deciduous	Lat: 6° 23' 29.8536" N and 0° 22' 46.3584" W
Aframase	Eastern	Semi-deciduous	Lat: N 6°21'4.75812" & Lon: W0°4'31.26"
Asesewa	Eastern	Semi-deciduous	Lat: 6.399516, & Lon: -0.141748
Gadza-Kpando	Volta	Semi-deciduous	Lat: N7°1'38.13708" & Lon: E 0°218'.48016"

The symptoms of the disease are characterised by irregular necrotic patches of brick red colour at the margins which enlarge and turn grey-silvery in colour covering major portions of the leaf surface (Figure 2 & 3).

Figure 2: Cashew leaves showing blight symptoms of grey-silvery colouration.

Figure 3: Cashew leaves showing blight symptoms and leaf spots.

These symptoms identified on tissues were common to all the sampling regions while few were more pronounced in certain areas than others. The cashew blight disease symptoms start as minute irregular necrotic patches of brick red colour at the margins which enlarge and turn grey-silvery in colour covering major portions of the leaf surface.

3.2 Identification of pathogens

The identities of fungi isolated included Lasiodiplodia spp., Pestalotia spp., and Colletotrichum spp. (Figure 4 and Table 2).

Figure 4: Cashew leaf blight pathogens isolated from infected leaves growing on PDA+ plates; (a) Lasiodiplodia spp., (b) Pestalotia spp. and (c) Colletotrichum spp.

Table 2: Some of the morphologically identified isolates from cashew leaf and other tissues different agro-ecological zones in Ghana

Sampling location	Ecological zones	Disease symptom	Suspected Organism
Bole	Guinea savannah	Leaf spots	Pestalotia spp.
		Leaf spots	Lasiodiplodia spp.
		Leaf spots	Colletotrichum spp.
		Leaf blight	Pestalotia spp.
		Leaf blight	Colletotrichum spp.
		Twig dieback	Lasiodiplodia spp.
		Twig dieback	Lasiodiplodia spp.
Wa	Guinea savannah	Leaf blight	Pestalotia spp.
		Leaf blight	Lasiodiplodia spp.
Techiman	Forest transitional	Leaf blight	Pestalotia spp.
		Leaf blight	Colletotrichum spp.
		Leaf blight	Colletotrichum spp.
Wenchi	Forest transitional	Leaf blight	Colletotrichum spp.
		Leaf blight	Pestalotia spp.
		Leaf blight	Pestalotia spp.
Aframase	Semi-deciduous	Leaf blight	Pestalotia spp.
		Leaf blight	Pestalotia spp.
		Leaf blight	Pestalotia spp.
		Leaf blight	Pestalotia spp.
		Leaf blight	Pestalotia spp.
		Leaf blight	Pestalotia spp.
Asesewa	Semi-deciduous	Leaf blight	Fusarium spp.
		Rots on nut	Cladosporium spp.
		Rots on nut	Cladosporium spp.
Begoro	Semi-deciduous	Leaf spots	Yet to be identified
		Leaf spots	Yet to be identified
Gadza-Kpando	Semi-deciduous	Leaf blight	Lasiodiplodia spp.

Most of the leaf blight isolates were morphologically identified and confirmed to be pathogenic through Koch's postulate. The isolates were mainly Pestalotia, Lasiodiplodia, and Colletotrichum species. One isolate from the Asesewa in the semi-deciduous ecological zone was identified to be of Fusarium spp. The leaf spots symptoms were identified to be caused by mainly Pestalotia, Colletotrichum and Lasiodiplodia pathogens while all the twig dieback symptoms were caused by Lasiodiplodia spp. However, two leaf spot isolates from Begoro in the semi-deciduous region are yet to be identified mainly because of lack of sporulation on media. All the leaf blight symptoms from Aframase were identified as Pestalotia spp. pathogens. The rots on nuts from Asesewa were caused by Cladosporium spp. No Colletotrichum pathogen was identified among the cashew leaf blight samples from the semi-deciduous region during the sampling.

3.3 Pathogenicity test

The pathogenicity test resulted in infection of the detached leaves. Some of the isolates were found to be virulent causing disease symptoms while others were non-virulent and therefore considered saprophytes (Figure 5). The pathogenic isolates were re-isolated from the infected leaves onto PDA media plates and identified to be the same isolates which were used to inoculate the leaves (Table 2).

Figure 5: Cashew leaves inoculated with fungal isolates using mycelial plugs and showing infection with lesions after 7 days of incubation at 25±2 °C. The non-diseased leaves (i.e., those without lesions) demonstrate non-virulent isolates.

3.4 Growth of isolates on different media

Inoculation of different media with mycelium plugs of seven selected leaf blight isolates (Table 3) showed varying radial growth on the media plates.

Table 3: A list of selected cashew leaf blight isolates inoculated on different media plates to assess growth.

Isolate code name	Identified organism
Lasiodi (1)	Lasiodiplodia spp.
Lasiodi (2)	Lasiodiplodia spp.
Lasiodi (3)	Lasiodiplodia spp.
Pestalotia	Pestalotia spp.
Lasiodi (4)	Lasiodiplodia spp.
Lasiodi (5)	Lasiodiplodia spp.
Colleto	Colletotrichum spp.

Comparison of the growth of the isolates on the different media showed that there were significant differences between the mean diameter of the isolates tested ($p < 0.001$) but no significant differences ($p = 0.673$) between the different media used for the growth assessment (Figure 6). However, pairwise comparison of Lasiodiplodia spp. (2), Lasiodiplodia spp. (3), Lasiodiplodia spp. (4) and Lasiodiplodia spp. (5) growth on media showed no significant differences between their mean diameters (Table 4).

Table 4: All pairwise multiple Comparison (Holm-Sidak method) of isolates mean diameter growth.

Comparison	Difference of Means	t	P	P<0.050
Lasiodi (4) vs. Pestalotia	53.375	9.313	<0.001	Yes
Lasiodi (4) vs. Colleto	52.458	9.153	<0.001	Yes
Lasiodi (2) vs. Pestalotia	51.188	8.931	<0.001	Yes
Lasiodi (2) vs. Colleto	50.271	8.771	<0.001	Yes
Lasiodi (3) vs. Pestalotia	45.563	7.95	<0.001	Yes
Lasiodi (5) vs. Pestalotia	44.771	7.812	<0.001	Yes
Lasiodi (3) vs. Colleto	44.646	7.79	<0.001	Yes
Lasiodi (5) vs. Colleto	43.854	7.652	<0.001	Yes
Lasiodi (1) vs. Pestalotia	26.896	4.693	<0.001	Yes
Lasiodi (4) vs. Lasiodi (1)	26.479	4.62	<0.001	Yes
Lasiodi (1) vs. Colleto	25.979	4.533	<0.001	Yes
Lasiodi (2) vs. Lasiodi (1)	24.292	4.238	<0.001	Yes
Lasiodi (3) vs. Lasiodi (1)	18.667	3.257	0.013	Yes
Lasiodi (5) vs. Lasiodi (1)	17.875	3.119	0.018	Yes
Lasiodi (4) vs. Lasiodi (5) *	8.604	1.501	0.639	No
Lasiodi (4) vs. Lasiodi (3) *	7.813	1.363	0.685	No
Lasiodi (2) vs. Lasiodi (5) *	6.417	1.12	0.785	No
Lasiodi (2) vs. Lasiodi (3) *	5.625	0.981	0.796	No
Lasiodi (4) vs. Lasiodi (2) *	2.188	0.382	0.974	No
Colleto vs. Pestalotia	0.917	0.16	0.984	No
Lasiodi (3) vs. Lasiodi (5) *	0.792	0.138	0.89	No

* Lasiodiplodia isolates showing no significant differences between their mean growth diameters.

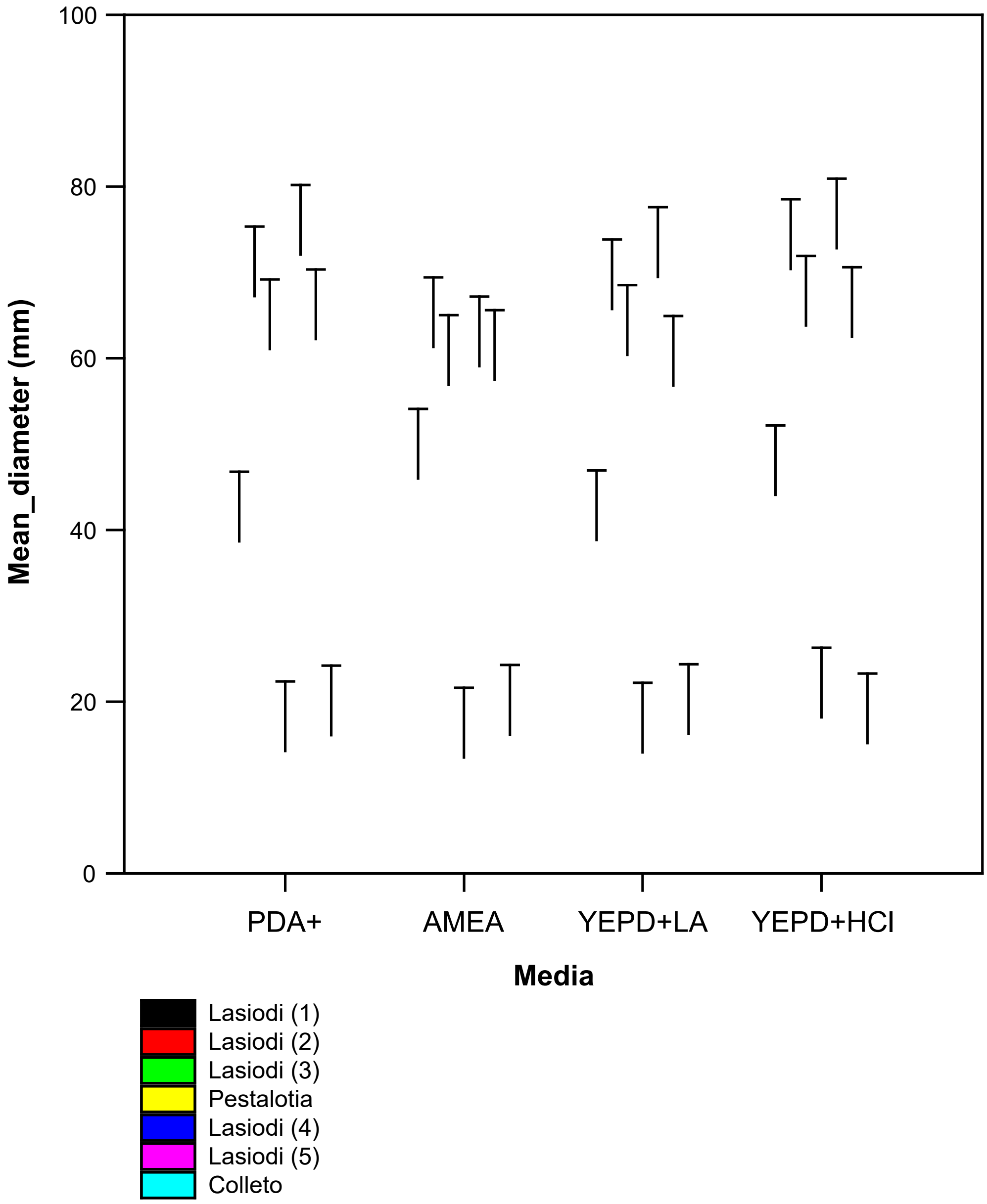


Figure 6: Comparison of cashew leaf blight isolates growth on different media incubated at 25±2 °C for 7 days. The bars represent standard error of the mean (SEM).

3.5 Effect of fungicides on cashew leaf blight disease pathogens

The percentage inhibition of the growth of Pestalotia spp. and Colletotrichum spp. on fungicide amended plates is shown in Table 5. All the pathogens tested were sensitive to the fungicides with percentage inhibition (PI) ranging from 80 % to 100 %. Pestalotia 1 spp., Pestalotia 3 spp. and Colletotrichum 3 spp. were completely inhibited by all the fungicides. Pestalotia spp. were generally more sensitive to the fungicides than the Colletotrichum spp.

Table 5: Percentage inhibition of mycelial growth of Pestalotia spp. and Colletotrichum spp. on PDA amended with different copper-based fungicides.

	Percentage Inhibition (%)			
Pathogen	CuOH	CU2O	Metalaxyl+CUOH	Metalaxyl +CU2O
Pestalotia 1	100	100	100	100
Pestalotia 2	95.5	94.2	90.5	100
Pestalotia 3	100	100	100	100
Colletotrichum 1	80	86.4	80.3	90
Colletotrichum 2	92.5	94	97.4	80.3
Colletotrichum 3	100	100	100	100

4.0 Discussion

Generally, the study showed that leaf blight symptoms are more acute in the Guinea savannah zone than the other cashew growing areas. This could be attributed to the environmental conditions in this zone resulting in cashew trees undergoing more stress and hence more susceptible to the cashew blight pathogens. Sampling cashew tissues from various farms in Wa (Guinea savannah), Bole (Guinea savannah), Techiman (Forest transitional), Wenchi (Forest transitional), Aframase (Semi-deciduous), Asesewa (Semi-deciduous), Begro (Semi-deciduous) and Gadza-Kpando (Semi-deciduous) resulted in the identification of different isolates from the diseased plant parts. Some of the isolates were virulent while others were non-virulent through the pathogenicity test (Koch's postulates). Culture characteristics and spore morphology was used in the identification process. The identified isolates include Lasiodiplodia spp., Pestalotia spp. and Colletotrichum spp. Most of the non-virulent isolates were suspected to be saprophytes and could not be identified using culture characteristics mainly because of lack of sporulation on agar plates. The pathogenicity test proved that Lasiodiplodia, Colletotrichum and Pestalotia species were responsible for cashew leaf blight disease. What was not determined in this study was the extent of the lesion development caused by these individual pathogens. Consequently, it would be necessary to investigate the cashew leaf blight disease severity by estimating lesion sizes after inoculation of the individual pathogens of the leaf blight disease complex. This would help to determine the relative importance of the three pathogens implicated in the disease complex for the development of targeted and effective management control systems.

Some of the virulent pathogens from the diseased tissues in this study were identified as Lasiodiplodia spp. and similar to the report from Nigeria (Olunloyo and Esuruoso, 1975) while others have been found to be Colletotrichum spp. and Pestalotia spp. Sijaona et al. (2006) reported Cryptosporiopsis spp. as the main pathogen responsible for causing leaf blight of cashew in Tanzania while L. theobromae has been associated with leaf blight and die-back of cashew inflorescence in Nigeria (Olunloyo and Esuruoso, 1975). The results of the current study therefore show that the pathogens responsible for leaf blight in Ghana are different from that of Tanzania but similar to Nigeria (Olunloyo and Esuruoso 1975) and Cameroon (Ngoh Dooh et al. 2021). This current result is also consistent with that of Assuah et al. (2008) where pathogens including Pestalotia, Colletotrichum, Lasiodiplodia, Penicillium and Aspergillus were implicated as responsible for cashew leaf blight in the northern region of Ghana. However, the current results extended the study to pathogenicity tests confirming the pathogenic status of the implicated organisms.

The isolated pathogens which have been identified using culture and microscopic features and confirmed through pathogenicity test would be further confirmed using molecular techniques. The confirmation of the pathogen's identity using molecular methods would enhance further epidemiological studies to be carried out including the influence of biotic (e.g., disease effectors) and abiotic factors (e.g., relative humidity, temperature, and light) on virulence of the pathogens. It is anticipated that the accurate identification of the pathogens would facilitate the evaluation of the resistance levels of recommended clones and hybrids of cashew to leaf blight diseases and also the designing of control methods including biological control and integrated pest management (IPM) systems. All the media tested (i.e., PDA+, AMEA, YEPD+LA & YEPD+HCl) supported growth of the isolates similarly. Interestingly, apart from Lasiodiplodia (1), all the other Lasiodiplodia isolates tested (i.e., 2, 3, 4 and 5) had similar radial growth sizes on all the media screened. The high efficacy of copper-based fungicides against pathogens causing leaf blight disease of cashew in vitro has been demonstrated in this study. The lowest PI obtained was 80 % whiles the highest PI was 100 %. Similar PI of 69.7 % to 100 % has been reported by Ngoh Dooh et al. (2021) when varying concentrations of Mancozeb 80WP fungicide was tested against Pestalotia heterocornis, the causal agent of cashew leaf blight disease in Cameroon. Fungicides such as difenaconizole, pecoxystrobin and chlorothalonil has been reported to be also effective in controlling cashew leaf blight disease caused by Cryptosporiopsis spp. (Majune et al. 2018). The use of synthetic fungicides in controlling fungal diseases of cashew has been widely reported (Majune et al 2018; Amoako et al. 2021). It is hoped that this study would add to the information required in designing effective control regimes for the management of cashew leaf blight diseases in Ghana. In the future, it is anticipated that other fungicide screening data would be incorporated into spray regimes and extended to farmer's farm studies.

Acknowledgements

This study was funded by the Cocoa Research Institute of Ghana (CRIG) and published with the kind permission of the Executive Director

References

Agyare, S., Magan, N., & Xu, X. (2020). Conditions for infection of strawberry fruit by M. piriformis and Rhizopus spp. European Journal of Plant Pathology, 157(1), 65–75. https://doi.org/10.1007/s10658-020-01981-3

Amoako-Attah, I., Awudzi, G. K., Acheampong, A. R., Asare, E. K., Bukari, H. Y., Avicor, S. W., & Ahadzi, S. K. (2021). Manual for the identification and management of cashew insect pests and diseases in Ghana (CRIG Technical Bulletin, No.29, 31 pp). Cocoa Research Institute of Ghana (CRIG).

Assuah, M. K., Opoku, I. Y., Dwomoh, E. A., & Oddoye, E. O. K. (2007–2008). Etiology and control of leaf blight disease(s) of cashew in Ghana: (Annual report, Cocoa Research Institute of Ghana. pp.156). Cocoa Research Institute of Ghana (CRIG).

Assuah, M. K., Opoku, I. Y., Dwomoh, E. A., & Oddoye, E. O. K. (2009–2010). Etiology and control of leaf blight disease(s) of cashew in Ghana: (Annual report, Cocoa Research Institute of Ghana pp. 173). Cocoa Research Institute of Ghana (CRIG).

Assuah, M. K., Opoku, I. Y., Dwomoh, E. A., & Yeboah, J. (2010–2011). Etiology and control of leaf blight disease(s) of cashew in Ghana: (Annual report, Cocoa Research Institute of Ghana. pp. 156). Cocoa Research Institute of Ghana (CRIG).

Humber, R. A. (2005). Entomopathogenic Fungal Identification (Updated version ed.). USDA-ARS Plant Protection Research Unit US Plant, Soil & Nutrition Laboratory Tower Road Ithaca, NY 14853–2901.

Kirk, P. M., Cannon, P. F., Stalpers, J. A., & Minter, D. W. (2008). Dictionary of the Fungi (9th ed.). CABI.

Majune, D. J., Masawe, P. A., & Mbega, E. R. (2018). Status and Management of Cashew Disease in Tanzania. International Journal of Environment, Agriculture and Biotechnology, 3(5), 1590–1597. https://doi.org/10.22161/ijeab/3.5.4

Mathur, S. B., & Kongsdal, O. (2003). Common Laboratory Seed Health Testing Methods for Detecting Fungi. International Seed Testing Association.

Menge, D. (2016). Studies on leaf and nut blight of cashew (Anacardium occidentale) caused by Cryptosporiopsis sp. in Tanzania. Plant Pathology & Quarantine, 6(2), 201–205. https://doi.org/10.5943/ppq/6/2/8

Moreira, R., Lima, J., Silva, L., & Cardoso, J. (2013). Resistance to gummosis in wild cashew genotypes in northern Brazil. Crop Protection, 52, 10–13. https://doi.org/10.1016/j.cropro.2013.04.008

Olunloyo, O. A., & Esuruoso, O. F. (1975). Lasiodiplodia floral shoot dieback disease of cashew in Nigeria [Lasiodiplodia theobromae, fungus diseases]. Plant-Disease-Reporter (USA), 59(2), 176–179.

Patrice, N. D. J., Placide, D., Madjerembe, A., Rony, M. T. P., Gabriel, D., Ulrich, B. F., Bouba, D., & Zachee, A. (2021). In vitro, In vivo and In situ, Effect of Mancozeb 80 WP on Colletotrichum gloeosporioides (Penz.) Penz. and Sacc., Causative Agent of Anthracnose of Cashew (Anacardium occidentale L.) in Chad and Cameroon. International Journal of Pathogen Research, 1–14. https://doi.org/10.9734/ijpr/2021/v6i330161

Sijaona, M. E. R., Reeder, R. H., & Waller, J. M. (2006). Cashew leaf and nut blight – a new disease of cashew in Tanzania caused by Cryptosporiopsis spp. Plant Pathology, 55(4), 576. https://doi.org/10.1111/j.1365-3059.2006.01365.x

Xu, X., Wedgwood, E., Berrie, A. M., Allen, J., & O'Neill, T. M. (2011). Management of raspberry and strawberry grey mould in open field and under protection. A review. Agronomy for Sustainable Development, 32(2), 531–543. https://doi.org/10.1007/s13593-011-0032-2

ECONOMIC ANALYSIS OF CASHEW APPLE VALUE CHAIN WITHIN THE COLLINES DEPARTMENT OF BENIN

Akanro R*. [1, 2], Kede R [2], Attanasso M. O. 2 and Dossou J. [3]

[1] Doctoral School of Economics and Management of the University of Abomey Calavi,
[2] Laboratory of Population Dynamics and Sustainable Development, Beninese Center for Scientific Research and Innovation
[3] Laboratory of Bioengineering of Food Processes, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 B.P. 526 Cotonou, Benin
*Email: akanroar@yahoo.com

Abstract

This study aims at providing an economic analysis of the valorisation of cashew apples as a means of significantly improving the income of the actors of this value chain in Benin. The sample of our study covers 110 participants and 30 groups in the cashew apple value chain within the Collines department during the 2020-2021 season. In terms of methodological approach, indicators of financial profitability of processing units where estimated. The results of this study reveal that on average, the income derived from cashew apples harvesting contributed to a 6% reduction in poverty of the harvesters. Poverty levels of the cashew apple juice traders reduced by 3.36% as a result of the income generated from the sale of the produce. Finally, processors of the cashew apples have sufficient income to take them out from below the poverty line with 135.8% reduction in poverty. Furthermore, we noted that 71% of the apple juice produced in the Collines department is exported to WAEMU countries, France, Germany and Israel.

Keywords: *Value chain, Poverty line, Profitability indicators, Cashew;*

1.0 Introduction

Cashew tree is grown mainly for its nuts, but this tree also provides the apple which is attached to the nut (Notebaert, 2019). The apples are often left to rot in the fields in Africa without properly being valorized. In West Africa, very little attention is given to cashew apple processing (Dossou et al., 2019), despite the fact that the economic potential of cashew apple juice is estimated at 70 billion FCFA with about 6 billion FCFA[1] in terms of additional income per year for Beninese producers (Yantannou, 2017). The literature currently available provides an overview of the valorisation of the cashew apple, however, very few studies have attempted to look into the economic benefits that could arise from the value addition of the apples. One of the few works that have addressed the economic aspect of the valorisation of cashew apples is that of Lawal et al. (2011) in Nigeria. However, the authors did not deal exclusively with the added value of cashew apple but cumulated the added value of the nut and apple in Nigeria.

The present study therefore aims to fill the gap in the literature by exclusively taking into account the processing of cashew apples. It seeks to first determine the value added to the transformation of cashew apple into juice by each actor in the value chain and then to identify the different sales channels of the apple juice produced in the Collines department in Benin.

2.0 Methodolgy

The study was conducted in two independent sites. The hybrids were developed as hand pollinated cashew nuts seeds which were planted at TARI Naliendele located at 10.38°S,

2.1 Study Area

An exploratory survey allowed us to identify the existence of about forty cashew apple processing units in Benin. These units are distributed in the departments of Collines (17 units), Borgou (10 units), Donga (6 units) and Atacora (7 units). This study took place in the department of Collines where the processing of cashew apples first began in Benin. In addition, it houses nearly half of the existing cashew apple processing units in Benin.

The department of Collines belongs entirely to the Sudano Guinean climate zone marked by two rainy seasons which cover the periods from April to July and from October to November. It is a transition zone (between the South and the North) of 16,900 km² which extends after the plateau of Abomey and that of Kétou to the 9th parallel north. This area is entirely occupied by leached or impoverished tropical ferruginous soils. These characteristics are very favorable to cashew cultivation. This department has six municipalities which are Dassa-Zoumé, Savalou, Bantè, Savè, Glazoué and Ouèssè.

1 1 dollar = 654.38 FCFA

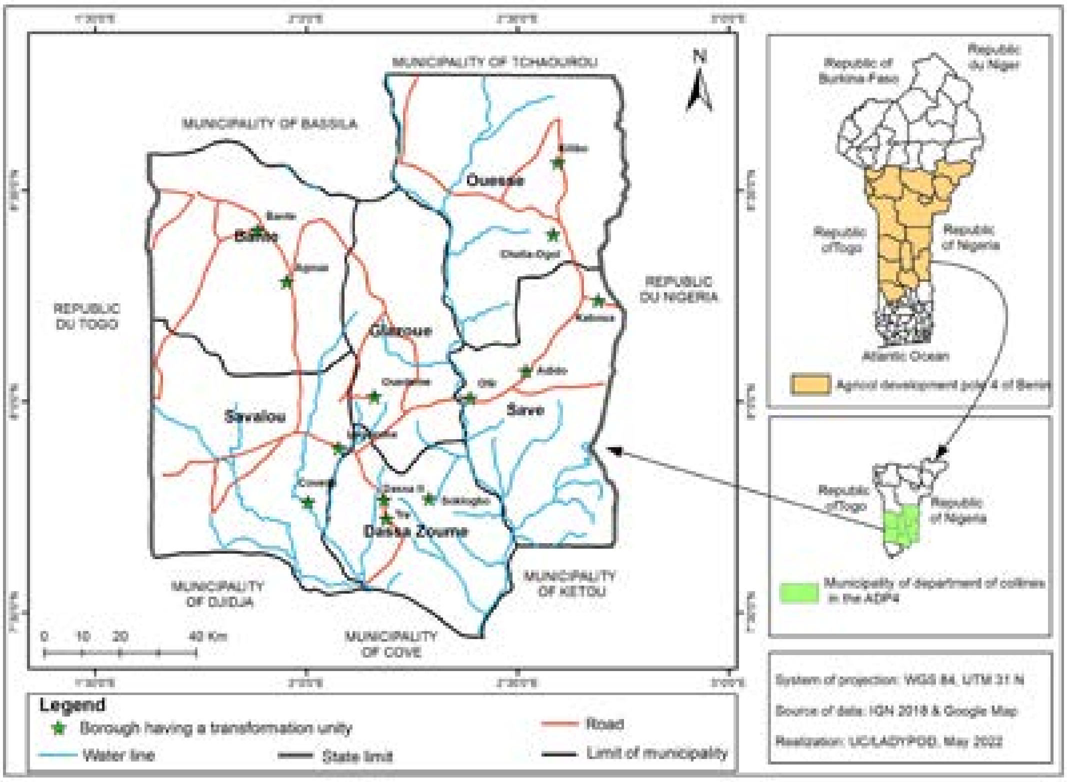


Figure 1: Distribution of the observation units in the Collines department.

2.2 Sampling

This study concerns the seventeen (17) existing processing units in the Collines department. Cashew apple collectors and traders were surveyed by the snowball method.

Table 1: Distribution of actors along the value chain

Value chain actors	Individual participants	Groupings
Cashew harvesters	78	0
Transformation units	2	15
Cashew juice traders	30	15
Cashew harvesters	78	0
Total	110	30

The number of individual actors represents the sum of the individuals working alone. The number of actors along the chain (nop) is the number of individuals involved in the same activity.

2.3 Data collection

Data was collected from stakeholders in the cashew apple value chain using a questionnaire built in the ODK software. The data collected were the quantities of apples processed, the purchase and selling price of apples, the quantities of juice marketed, the selling price of the juice, destinations, working time, equipment and materials used...

2.3.1 Data analysis and processing

Destination of the juice produced in the observation units

The ArcGIS software was used to map the sales channels of the juice produced and to determine the different destinations of this juice inside and outside Benin.

Estimation of the financial profitability indicators of the value chain

The average cost of processing apple into juice (Ct) according to the (Springer-Heinze A., 2018) formula

üüüü ü üüü ü (1)

With

C_{fp} = the fixed cost of production;

C_{vp} = the variable cost of production;

Q_t = the quantity of apple processed into juice per processing unit;

$(C_{fp} + C_{vp}) / Q_t$ = the average production cost per unit into juice

nam : the number of actors per link.

i : an actor

The average unit marketing cost (Cc) was calculated similarly üü ü üüüü (2)

With

C_{fc} = the fixed cost of marketing;

C_{fc} = the variable cost of marketing;

Q_c = the quantity of juice marketed by each unit;

C_c is expressed in FCFA/liters.

The average apple harvesting cost (Ch) was calculated similarly üüüü ü üü ü (3)

With

C_{fh} = the fixed cost of harvesting;

C_{vh} = the variable cost of harvesting;

Q_{ch} = quantity of juice marketed by each unit

Ch is expressed in FCFA/litters.

The costs consist only of the variable harvesting and marketing costs (fuel, travel costs). Equation (2) becomes: üüüü ü üü ü (4)

Equation (3) becomes: üüüü ü üü ü (5)

The margin (Mt) from the processing of the cashew juice is established according to the Springer-Heinze relationship (2018)

ü ü = (6)

Were,

Pv is the unit selling price of the product.

Cj is the cost of the corresponding value chain link.

The margin (Mp) from the cashew marketing was calculated using: ü ü = (7)

The margin (Mj) from the marketing of cashew juice was calculated using: ü ü = (8)

The rate of profitability (r) is obtained by the formula:

ü (9)

ü (10)

I : Income which is expressed in FCFA; M is the production or marketing margin. The contribution of income to the reduction poverty

(Cp) is established by: ü ü (11)

Sp is the reference poverty line for the year the data was collected, which was 1,401.73 FCFA/day or 504,622.8 FCFA per adult person/year in 2022 (World Development, 2022).

Estimation of economic performance indicators of the Value chain

The employment created by the CV, is expressed by:

E = (N x Tm) /8

- Tm is the average time (h) devoted to the activity, adjusted for the quantities produced. Eight hours of work were considered to correspond to one working day. E is expressed in working days (jt).

- The income of a link in the value chain is obtained by multiplying the income received by each direct actor by the number of actors in the link considered. Thus, the total income of the Value Chain was obtained by summing the income of all the different links in the chain.
- the added value created by all the players at each step of the value chain is estimated using the following formula from Faße A. et al., (2009):
- VA = CA – CI

CA represents the revenue in FCFA; CI, the intermediate consumption in FCFA.

The total value added was obtained by summing the value added of all the links.

3.0 Results

3.1 Description of the cashew apple value chain in Benin

Cashew apples are collected from cashew plantations to be processed into juice, syrup, wine and liquor. This activity is carried out by harvesters and processing units. Most processing units have rolling stock called tricycles that allow them to go from farm to farm in order to buy selected apples from harvesters. The purchased apples are transported to the processing units in the villages and towns of the various communes of the Collines department where these apples are transformed after a process that generally last for 10 hours. The juice is then sold in the city centers of Benin and is also exported outside Benin.

3.2 Value added to cashew apple juice by actors in the cashew apple value chain

Table 2 below shows that the harvesting of the cashew apples has the highest profit margin with a profitability of 86.66%, followed by the apple juice processing which boast of profitability of 76.75% and the actual commercialisation of apple juice is the activity which has the smallest profit margin with a profitability of 15.64%. This is generally due to the fact that there is less cost involved in the harvest of the apples as compared to processing and marketing.

Table 2: Margins of participants and profitability of products at each step of the cashew apple juice value chain

Link in the Value chain	Sale price(FCFA)	Average Cost Of Production/ Marketing (FCFA)	Margin (FCFA)	Profitability
Cashew harvest (per kg)	19,28(0,56)	0,23(0,04)		86,66
Cashew juice processing (per l)	1473,16(543,10)	614,12 (152,34)	859,03 (408,54)	76,75
Marketing	Margin (FCFA)	Profitability		
of the juice (per kg)	1200(0)	1037,26(143,98)	162,72	15,64

NB : The values in brackets represent standard error

A look at the contribution of each stage in reducing poverty (Table 3) shows that a harvester would see his/her poverty level reduced by almost 6%, while a trader would see his/her poverty level reduced by 3.38%. Finally, players at the processing stage see the most benefits as their poverty level reduce by a staggering 135.80%. Hence we n1oted that the activity of processing cashew apples makes it possible to completely move from below the poverty line.

Table 3. Contribution to poverty reduction of participants in the value chain

Link in the value chain	Contribution to poverty reduction (%)
Harvesting of the cashew (per kg)	5.99
Processing into juice (per l)	13,580
Commercialisation of the juice (per kg)	3.38
of the juice (per kg)	1200(0)

In terms of employment potential (Table 4), the cashew apple value chain in the Collines department mobilized at least 14,461 working days (JT) for a production of 5,888 liters of apple juice in 2021; the processing activity created more jobs with a contribution of 12,875 working days. Overall, the current income and added value received by all actors are 146,647,571.7 and 123,269,874 FCFA respectively.

Table 4. Jobs creation and contribution of the apple processing value chain to income and the adding of value to the participants

Activity	Jobs	Intermediate Consumption (FCFA)	Participants Income (FCFA)	Value Added
(FCFA)	19,28(0,56)	0,23(0,04)		
Harvesting	1,485	0	2328755,04	2328755,04
Processing	12,875	23,377,698	143807000	120429302
Trade	101	0	511816,6677	511816,668
Cashew apple juice value chain	14,461	23377,698	146647571,7	123269874

3.3 Distribution of cashew apple juice produced in the processing units

The analysis of Figure 2 below reveals that in 2021, 13% of the cashew apple juice produced in the Collines department in Benin was consumed in the Southern of the country, 6% was consumed in the North and 10% in the Central regions of the country. In addition, 20% of the juice was exported to WAEMU countries such as Burkina-Faso, Niger, Togo and Senegal. In Europe, 23% of the juice produced was consumed in France and 9% in Germany. The remaining 19% was consumed in Asia, mainly in Israel. In short, 71% of the cashew apple juice produced in the Collines department is exported to WAEMU, European and Asian countries. France is the biggest consumer of the cashew juice outside of Benin

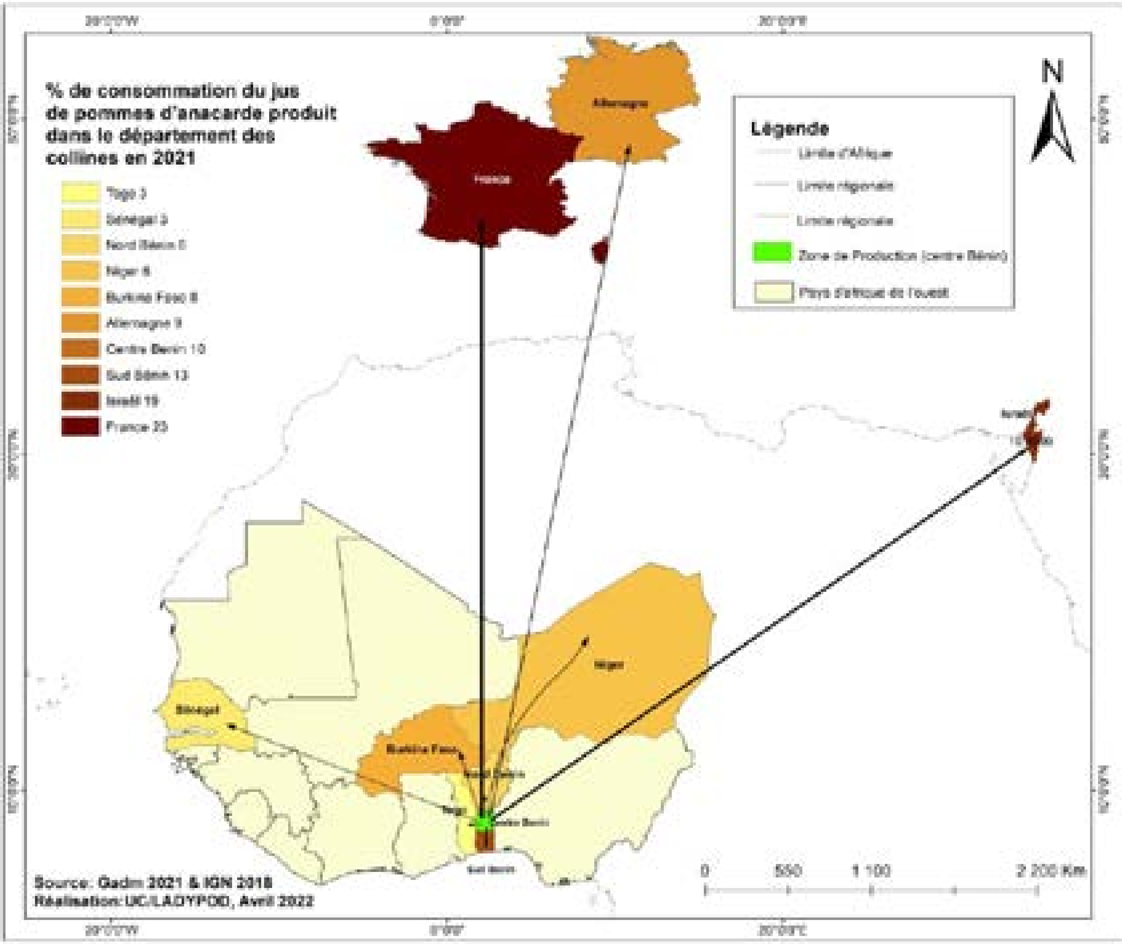


Figure 2: Sales channel of the cashew apple juice produced in the Collines department in Benin.

4.0 Discussion

The juice produced in the Value Chain has enabled the participants to earn positive margins. The price at which each participant sold the product allowed them to make a profit. The cashew apple processing activity is economically profitable. Work carried out in Togo by (SAMAROU et al., 2022) on tamarind value chain resulted in a margin of 22 per cent for the Marketing of the juice. Comparatively, the margin of 15 per cent generated by the marketing of cashew apples is lower. This is because tamarind is a familiar product with a developed marketing chain unlike cashew juice. The positive margins generated by all the participants allowed them to contribute to the reduction of monetary poverty in the Collines department. While the harvesting and merchant links contribute little to the reduction of monetary poverty (less than 10%), the processing link completely falls outside the monetary poverty line (135.80%). This last result is conformed with work of VanRayne and al (2022) and is higher than that of Chadare and al (2008) which found a monetary poverty reduction threshold of 33% in baobab juice value chain.

The export rate of 71% of apple juice produced in the Collines department is similar to that of pineapple export crop produced in Benin.

Indeed, the work of the National Institute of Statistics and Economic Analysis (INSAE, 2020) reveals that 80% of the fresh and dried pineapple produced in Benin is exported. In addition, the proportion of cashew apple juice sold on the local market, which is 29%, is higher than that of pineapple juice and syrup sold on the local market. According to INSAE (2020), 15% of pineapple juice and syrup are sold on the local market in Benin. However, holding everything else constant, the quantity of cashew apple juice produced in Benin is insignificant compared to the quantity of pineapple juice produced. It should be noted that the 15% of pineapple juice consumed is more than the 29% of apple juice consumed in quantity. There is still a long way to go to achieve sufficient valorisation of the cashew apple in Benin.

Conclusion

This study analyzed the economic valorisation of cashew apples into juice in the Collines department in Benin. More clearly, the study determined the real impact of the value chain and its contribution to poverty reduction. Although the highest profit margin in the cashew apple value chain is realised at the harvesting level, harvesters end up with the lowest income in the value chain. In addition, the study of the sales channel of cashew apple juice produced in the Collines department has revealed that the product is mainly consumed beyond Benin's borders.

Recommendations

At the end of this study, we suggest that the actors of the cashew apple value chain get together in order to work out a fairer distribution of the income from the Value Chain. We also encourage cashew apple processing units to standardize the juice obtained in order to obtain the protection against the collective mark of apple juice on the one hand and to obtain cost reduction advantages for export cashew apple juice. Government support is also necessary to meet the challenges related to the non-valorization of cashew apples in Benin.

Acknowledgements

We thank Technoserve for its financial support. We are also grateful for the help provided by Mr. N'DJOLOSSE Kouami, Head of the Cashew nut program in Benin and the cashew nut sector actors of the Collines Department in the realization of this work..

References

Chadare, F., Hounhouigan, J., Linnemann, A., Nout, M., & Van Boekel, M. (2008). Indigenous knowledge and processing of Adansonia digitata L. food products in Benin. Ecology of food and nutrition, 47(4), 338-362.

Dossou et al. (2019). Etude des performances techniques d'un filtre-presse pour la filtration du jus de pomme d'anacarde (anacardium occidentale l.). Afr. J. Food Agric. Nutr. Dev. 2019, 19(3), 14690-14707. https://doi.org/10.18697/ajfand.85.17380

Faße A., Grote U., & Winter E. (2009). Value chain analysis methodologies in the context of environment and trade research, discussion papers.

Notebaert, C. (2019). Système alimentaire et politiques agraires a l'ombre des pommiers-cajou : Les dynamiques agraires et alimentaires liées a l'anacardier dans le Nord-Est du Bresil (sistema alimentar e política agrária nas sombras dos cajueiros : As dinâmicas agrárias e alimentares ligadas ao cajueiro no nordeste do brasil). Revista geonordeste, 2, 6-19. https://doi.org/Https://doi.org/10.33360/RGN.2318-2695.2019.i2especial.p.6-19

Samarou, M., Atakpama, W., Atato, A., Mamoudou, M. P., Batawila, K., & Akpagana, K. (2022). Valeur socio-économique du tamarin (Tamarindus indica) dans la zone écologique I du Togo. Revue Marocaine des Sciences Agronomiques et Vétérinaires, 10(2).

Springer-Heinze A. (2018). ValueLinks 2.0. : Manual on sustainable value chain development. 2.

van Rayne, K. K., Adebo, O. A., Wokadala, O. C., & Ngobese, N. Z. (2022). The potential of Strychnos spp L. utilization in food insecurity alleviation : A review. Food Reviews International, 1-15.

World Development. (2022). Finance for an equitable recovery (World development report). World Development. www.banquemondiale.org

Yantannou, S. (2017). Sweet Benin – La douceur de la vie!

EFFECT OF DRY CASHEW APPLE PULP IN CAIPIRA AND NAKED-NECKED CHICKEN DIETS IN GUINEA- BISSAU (A PRELIMINARY INVESTIGATION).

Yisa I.K.

Center of The Development of Family Aviculture (CEDAVES) / Asas do Socorro. Bissau, Guinea-Bissau

Abstract

Cashew apple which constitutes about 90% by weight of the cashew fruit, is largely left to rot as whole apples or waste from the cashew beverage industry. The poultry industry in Guinea-Bissau is at its lowest ebb because of high cost of feed, as the major ingredient in the feed formulation is largely imported. Dry cashew apple pulp (DCAP) has been reported to be profitable when used to replace maize in broiler feed. This experiment was therefore carried out to study the effect of DCAP on caipira and naked necked dual-purpose birds being promoted in the country. Fresh cashew apples were collected, the juice was extracted manually, and the residue was dried to about 12% moisture content. This was incorporated into the chicken diet by replacing 10% maize content in CEDAVES broiler starter, grower, and finisher diets with DCAP. Fifty (50) birds were divided into two groups and fed with either commercial feed or 10% replacement of maize in the feed with DCAP for 45 days. Feed intake, weight gain, feed conversion and cost of feed were monitored. Feed intake was higher for birds fed on diet with 10% DCAP inclusion than only maize-based diet. - 313.02g/303.10, 1,238.52g/1,210.08 and 1,766.64g/1766.64g at the starter, grower, and finisher phases respectively. There were no significant differences in feed intake and weight gain. Overall feed consumption was 3,318.18g/3,198.82g. Weight gain/bird was 146.96g/134.68g, 362.24g/426g and 521.41g/366.63g at the starter, grower, and finisher levels respectively in birds with 10% DCAP inclusion versus birds with maize based diet. Overall weight gain/bird was 1,030.61g/928.03g in 10% DCAP inclusion and non DCAP diets. DCAP lowered cost of feed /bird by 2.17, 3.78 and 1.36% at the starter, grower, and finisher phase respectively. DCAP reduced cost of feed by 2.30% for meat production. Cashew apple when dried adequately can efficiently lower the cost of chicken meat production and increase the value of cashew apple thereby enhancing cashew value chain.

Keywords: Cashew, cashew apple, dried cashew apple pulp, meat chicken, cost.

1.0 Introduction

The cashew apple is largely under exploited. Catarino et al. (2015) reported an estimated annual production of 1,500,000 tonnes of cashew apples in Guinea-Bissau. This according to the authors could be an important raw material for value addition. Uses of cashew apple include consumption as fresh fruit during production season, and processing of its juice into both alcoholic and non-alcoholic drinks. However, it has been generally reported that only about 10% of the apple is utilized (Attri 2009, Akyereko et al. 2022.

Maize is a major component in poultry feed, the cost of which has a great effect in the price of poultry feeds. Guinea-Bissau presently does not produce sufficient maize to sustain its growing poultry industry. According to Thirumalaisamy et al. (2019), the cost of maize along with other feed ingredients ranges between 60-70% of the total cost of raising poultry. It has become pertinent to source for locally available feed resources to combat the increasing cost of feed due to the market price of conventional feed ingredients. In Niger, Burkina Faso and Mali, the price of maize changed from an average of 200 FCFA /kg to 240 FCFA /kg between October and December 2020 (FEWS NET, 2022). By June 2022, maize price has increased between 280-320 FCFA/kg in Guinea-Bissau and neighboring countries.

Cashew apple is in its abundance during the cashew harvest and is largely left to rot on the plantations. Harnessing the potential of available cashew apples by sun drying could reduce the dependence on maize and enhance the income of cashew farmers. Swain et al. (2014) fed growing and laying quails with different levels of dried apple waste. Kardivel et al. (1993) and Nghi et al, (1995) also fed cashew apple waste as replacement for maize and other energy sources to broilers. In India, Swain and Barbuddhe (2014) replaced up to 10% commercial layer feed with dried cashew apple waste in diets of the local Vanaja layers. Yisa (2019) replaced up to 20% maize with dry cashew in broiler chicken diets. There is paucity of information on the use of dry cashew apple pulp in poultry feed in Guinea-Bissau. This experiment was therefore carried out to study the suitability of DCAP in bird diets.

2.0 Materials and Methods

The experiment was carried out in Farim, an outstation of CEDAVES Bissau. Farim is situated on latitude 27.2046° N and longitude 77.4977E in Guinea-Bissau. Cashew apple waste from the alcoholic beverage industry was collected and sundried. It was ground and sieved through a mesh of 2mm and incorporated into the test diets. Using a two-group randomized experimental design, 50 one-week old caipira and naked-necked birds were allocated to two litter pens. The birds were raised on a litter system. The chickens were brooded for two weeks using charcoal pot as the source of heat and dry battery cells provided illumination at night. Temperature was monitored during the brooding period. Feed and water were provided ad libitum. The dietary treatment consisted of 0% and 10% replacement of maize with DCAP at the starter and finisher phases. The presentation of the feed was in mash form. Data collected were feed intake and weight gain. Feed conversion and cost of feed were calculated.

All data collected were subjected to t-Test. The experiment lasted for 45 days. The proximate composition of DCAP is shown on Table 1. The gross composition of starter, grower and finisher diets of caipira and naked necked chickens fed DCAP in replacement for maize is as shown on Table 2

Table 1: Proximate composition of dried cashew apple pomace (pulp)

Parameters	%Dry matter
Dry matter	88.40±2.05
Moisture content	11.60±2.05
Crude protein	12.60±1.26
Ether extract	5.14±0.23
Crude Fibre	9.17±0.23
Total ash	5.88±0.46
Nitrogen Free Extract	67.21±2.18
Gross energy (kcal/kg)	4227.55±5.45

Source: Utilisation of Cashew (Anacardium occidentale L.) apple pomace

as a source of energy by broiler chickens. Yisa, 2019

Table 2: Gross composition of starter, grower and finisher diets of caipira and naked necked chickens fed dry cashew apple pulp in replacement for maize

Ingredients	Group1 0%DCAP Starter diet	Group2 10%DCAP	Group1 0%DCAP Grower diet	Group2 10%DCAP	Group1 0%DCAP Finisher diet	Group2 10%DCAP
Maize	58.0	52.2	64.5	58.05	64.5	58.05
Soyabean Meal	25.4	25.4	18.6	18.6	18.6	18.6
Fishmeal	9.0	9.0	8.0	8.0	8.0	8.0
*Premix (CMV	3.0	3.0	3.0	3.0	3.0	3.0
Chickens-1,2,3) Soyabean oil	2.5	2.5	2.5	2.5	2.5	2.5
Rice bran	1.8	1.8	3.2	3.2	3.2	3.2
Oyster shell (G-	0.25	0.25	0.15	0.15	0.15	0.15
Bissau)Refined salt	0.05	0.05	0.05	0.05	0.15	0.15
Total	100	100	100	100	100	100

3.0 Results

Table 3 shows the performance characteristics of the birds fed with or without DCAP diet. Although, birds fed on DCAP diets consumed more feed at every stage of the experiment, differences in feed intake were not significant between the two groups. At the starter phase birds fed with no DCAP diet (0% DCAP) consumed an average amount of 303.10g as against 313.02g/chicken for treatment with 10% DCAP. Similarly, at the grower phase, birds on 0 % DCAP treatment consumed an average of 1,210.08g/bird as against 1,238.52g/bird on 10 % DCAP treatment. The finisher phase followed the same trend (1,686.64g /1766.64g per bird on 0 % DCAP and 10 % DCAP in diets respectively). Total feed consumption for birds on 0 % DCAP was 3,198.82g as against 3,318.18g/bird in 10 % DCAP diet.

At the starter phase birds on 10% had higher weight gain with an average of 146.96g while weight gain for birds on diet with 0 % DCAP was 134.68g. This was reversed at the grower phase with birds on 0 % DCAP diet having an average of 426.72g and 10 % DCAP with 362.24g. However, at the finisher phase, 10 % DCAP treatment had an average weight of 521.41g while 0 % DCAP treatment had 366.63g. Total weight gain was higher in birds with DCAP with an average of 1,030.61g as against 928.03 in birds with no DCAP in their diets. However, weight gain was not significantly affected during the study.

Feed conversion ratio was lower at the starter and finisher phase for birds on 10% DCAP treatment with the values of 2.12/2.25 and 3.39/4.60 respectively. On the other hand, feed conversion ratio was lower in chickens with 0% DCAP at the grower phase 2.84/3.42. The overall feed conversion ratio was lower in birds with 10% DCAP in their diet.

Table 4 shows the cost implication of replacing maize with DCAP in the diets of caipira and naked necked chicken. Inclusion of DCAP in broiler starter diet reduced cost of feed per kg by 17.41FCFA, of the grower diet by 19.85FCFA and finisher by 19.27FCFA. The cost of feed consumed per bird during the different phases was lowered by the replacement of maize with DCAP. Comparing the two treatments (0%/10% DCAP), cost of feed consumed is as follows: starter phase 100.02/97.85 FCFA, grower phase 399.90/384.75FCFA, the finisher phase 556.38/,548.81FCFA and the whole rearing phase 1056/1031.41FCFA . Feed cost per kg body weight is lowered by 137.03 FCFA.

Parameters	Group1 (Without DCAP)	Group 2 (With DCAP)
Feed intake(g) 7-20days	303.10	313.02
21-35days	1210.08	1238.52
36-45days	1686.64	1766.64
7-45days	3198.82	3318.18 NS
Weightgain(g)7-20days	134.68	146.96
21-35days	426.72	362.24
36-45days	366.63	521.41
0-45days	928.03	1030.61 NS
Feed conversion Ratio 7-20days	2.25	2.12
21-35days	2.84	3.42
36-45days	4.60	3.39
0-45days	3.45	3.23NS

Table 3: Performance characteristics of caipira and naked necked chickens fed diets with or without dry cashew apple pulp

NS – Not significantly different p>0.05

Table 4: Cost implication of replacing maize with DCAP in the diets of caipira and naked necked meat chickens

Cost	Group1(Without DCAP)	Group2(With DCAP)
Cost of feed/kg FCFA		
7-20 days	330.00	312.59
21-35 days	330.47	310.65
36-45 days	329.92	310.65
Cost of feed consumed/bird		
7-20 days	100.02	97.85
21-35days	399.90	384.75
36-45 days	556.38	548.81
7-45 days	1056.82	1031.41
Total feed consumed/kg body		
Weight		
7-20 days	2.25	2.12
21-35 days	2.84	3.42
36-45 days	4.60	3.39
7-45 days	3.45	3.23
Feed cost/kg body weight		
FCFA (7-45days)	1138.81	1000.78

4.0 Discussion

Feed intake was higher in the birds fed with 10% DCAP throughout the three feeding phases. This could be due to bulkiness of DCAP in comparison with maize. Monogastric animals attempt to increase feed intake when given diets that contain increasing levels of non-starch polysaccharides (NSP). This is probably an attempt to maintain the rate of available energy intake. Increased feed intake has been recorded in use of non-conventional feed ingredients (Yisa 2019, Ayhan et al. 2009). Weight gain also increased at the starter and finisher levels, but not at the grower phase. The latter is in agreement with the result of Yisa (2019). Feed conversion was lower at all phases except at the grower phase. Cost of feed production was lower for feed with DCAP and cost of feed intake per bird was lower for birds on the feed. This is supported by Swain et al. (2014) who reported cost reduction in the use of non-conventional feed material. In a study carried out by Yisa (2019), cost per gain was higher for birds fed different levels of DCAP than birds fed only maize in their diets. It can therefore be concluded that DCAP can successfully replace maize at 10% level for profitable commercial broiler production.

Recommendation

There is the need for further research into various levels of DCAP inclusion in broiler feed and its utilization in egg production. The DCAP is hereby recommended for pilot testing among poultry farmers to enhance scaling up of the processing of cashew apple for poultry feed.

References

Akyereko Y.G., Wireko-Manu F.D., Alemawor F. and Adzanyo M. Cashew apples in Ghana: Stakeholders' knowledge, perception and utilization. International Journal of Food Science, vol.2022, Article ID 2749234, 10 pages, 2022. https://doi.org/10.1155/2022/2749234

Attri, B.L.2009. Effect of initial sugar concentration on the physico-chemical characteristicsand sensory qualities ofcashew apple wine. Natural Product Radiance 8:374-379

Ayhan V., Arslan Duru A. and Ozakaya S. 2009. Possibilities of using dried apple pomace in broiler chickens. Kafkas Universitesi Veteriner Dergisi 15:5

Catarino L., Menezes Y. and Sardihna R.Cashew cultivation in Guinea-Bissau- risks and challenges of the success of a cash crop. Scientia Agricola[online]. 2015,l, v.72, n.5 [Accessed 4 December 2021], pp 459-467. Available from: https//doi.org/10.1590/0103- 9016-2014-0369>. ISSN 1678-992X. https://doi.org/10.1590/0103-6016-2014-0396

FEWS NET 2022.West Africa Price Bulletin, January 2022 https://reliefweb.int/report/mali/wesr-africa-price-bulletin-january-2022

Kardivel R., Mohan B., Natarajan A. and Bhaskaran M. 1993. The value of cashew apple (Anacadium occidentale) meal in broiler rations. Tropical Agriculture 70, 294

Nghi N., Khang D.N. and Cai D.V. 1995. Study of processing and using cashew residues as animal feeds. A report in the project: "Improve the value of cashew apple" sponsored by CRDI

Swain B.K. and Barbuddhe S.B. 2014. Use of agro- industrial by products to economise feed cost in poultry production. Technical Bulletin 13: 402-403

Swain B.K., Naik P.K. and Singh N.P. 2014. Unconventional feed resources for efficient poultry production. Technical Bulletin 47:1-55

Thirumalaisamy G.,Purushothaman M.R., Vasantha Kumar P. and Selvaraj P. 2016. Effect of feeding cotton seed meal on some haematological and serum biochemical parameters in broiler birds. Veterinary World. 2016 July; 723-727 doi:10.14202/vetworld.2016.723-727

Yisa I.K. 2019. Utilisation of Cashew (Anacardium occidentale L.) apple pomace as a source of energy by broiler Ph,D Thesis http://repository.pgcollegeui.com

MORPHOLOGICAL, NUTRITIONAL AND QUALITY ASSESSMENT OF CASHEW (*ANACARDIUM OCCIDENTALE L.*) NUTS FROM 53 ACCESSIONS OF BURKINA FASO

SemporéJ. N.[1] *, Songré-Ouattara L. T. [2], Tarpaga W. V. [3], Bationo F. 2, Dicko M. H. [1]

[1] Laboratory of Biochemistry, Biotechnology, Food Technology and Nutrition (LABIOTAN), UFR-SVT, University Joseph Ki-ZERBO, 09 PO. Box 848, Ouagadougou 09, Burkina Faso
[2] Institute of Research for Applied Sciences and Technologies (IRSAT), Food Technology Department, CNRST, 03 PO. Box 7047, Ouagadougou 03, Burkina Faso
[3] Institute of Environment and Agricultural Research (INERA), National Centre for Specialization in Fruits and Vegetables, CNRST, 01 P O Box 910, Bobo-Dioulasso 01, Burkina Faso
*Corresponding author: semporej@gmail.com / (+226) 74 55 39 28

Abstract

Cashew nuts (Anacardium occidentale L.) are important on the world market, including Burkina Faso. However, nut production from trees remains low in Burkina. This has stimulated the establishment of a breeding program on the species, targeting cashew accessions with high profitability, food quality and economic interest. The present study consisted of a morphological and nutritional characterization of 53 cashew accessions from western Burkina Faso for the development of more profitable and competitive varieties on the international market. Morphological characteristics including length, width, thickness, weight, kernel yield and commercial quality, mainly seediness and kernel outturn ratio (KOR) were evaluated by standard methods. Nutritional analyses included moisture, lipid, carbohydrate, protein, ash, cellulose and energy content using standard methods. The results showed that the nuts had an average weight of 6.71 ± 1.13 g, with length, width and thickness of 3.15 ± 0.5 cm, 2.54 ± 0.22 cm and 1.75 ± 0.23 cm respectively. The samples were predominantly composed of large nuts with 86.79% of the nuts in the cashew accessions having a kernel size of less than 180 nuts/kg. More than half of the accessions had a very good KOR above 50 pounds. Regarding the nutritional analysis of the kernels, it was found that lipids had high average content of 50.71 ± 4.07%, and represented the majority constituent, followed by carbohydrates and proteins with average contents of 21.18 ± 3.81% and 20.62 ± 1.58% respectively. As for the average contents of moisture, ash and cellulose, were 4.56 ± 0.39%, 2.87 ± 0.27% and 4.61 ± 2.52% respectively. The analysis of the variability within the accessions, based on the nutritional parameters, allowed the identification of 3 groups which are differentiated by the richness in lipids, carbohydrates, proteins, cellulose and energy value. The hierarchical ascending classification according to morphological parameters allowed to distinguish four groups of nuts that were differentiated by weight, graining, kernel yield and KOR. The cross analysis of the characters allowed the identification of 35 accessions out of 53 that present agricultural, nutritional and commercial performances for varietal selection programs.

Keywords: Cashew, cashew accession, KOR, seediness, nutritional.

1.0 Introduction

The cultivation of cashew (Anacardium occidentale L.) is of great economic, environmental and social interest worldwide. The tree is an important cash crop due to the increasing demand for its nuts and shell liquid. The global production of raw cashew nuts is estimated at 3,396,680 tons with a cultivated area of 3,276,756 ha in 2019 (FAOSTAT, 2019). Africa, with a production of 2,334,405 tons, is the largest producer and exporter of cashew nuts in the world accounting for more than 50% of production. West Africa's 2019 production was 1,696,417 tons. In Burkina Faso, recent data collection yielded a production of 136,558 tons with a cultivated area of 130,011 ha (FAOSTAT, 2019). Cashew was introduced to Burkina Faso in the 1960s (Hiema, 2011) for the regeneration of the vegetation cover. The development of the plant represents an economic opportunity dueto the nutritional and medicinal potential of its fruits. Thus, the fruits of the tree, especially the nuts, have become an export commodity. With an estimated export of 117.11 billion CFA francs in 2018, cashew nuts represent the third largest export product after cotton and sesame (INSD, 2020).

To better support cashew cultivation, Burkina Faso has implemented a cashew industry development strategy and created a Burkina Cashew Council. Despite these favorable policy conditions, many constraints still hamper the sector, such as low and uncontrolled production and the lack of characterization of varieties by breeders. With an average density of 100 trees per hectare, the average yield is less than 4kg/tree, which is very low (Tarpaga et al., 2020). Like most cashew plantations in Africa, the low tree yield is related to the lack of improve planting material selection programme (Aliyu & Awopetu, 2011). The current challenge for the cashew value chain is mainly to increase its productivity and nut quality for local processing and the international market (Ndiaye et al., 2020). This will stimulate rural development and generate more income for farmers. Indeed, seediness (number of nuts) and kernel outturn ratio (KOR) are the main criteria used to determine cashew nut quality (DDP, 2002) (Stéphane et al., 2020).

In Burkina Faso, a cashew varietal improvement program initiated in 2011 by the breeders has so far identified trees with high productivity and good raw nut quality in the main production areas (Tarpaga et al., 2020). The present study aimed at the morphological, nutritional characterization and evaluation of nut quality of a core collection of 53 cashew accessions. This will contribute to a better characterization of the plant material under selection and the development of more profitable and competitive cultivars on the international market.

2. Material and methods

2.1. Plant material

Plant material was previously described by Tarpaga et al., (2020). It consisted of 53 cashew accessions, under advanced selection, identified as genetically different from each other by agro-morphological traits. Mass selection processes were used to select the core collection from a population of 820 landraces candidates. The nuts of these cashew accessions were collected in 2020 in nine departments located in two regions of Burkina Faso, namely Hauts-Bassins and the Cascades (Table 1).

Table 1: Origins/area and years of collection of cashew accessions

Regions	Provinces	Departement	Number of cashew accessions	year of survey and characterisation	year of nut collection	Accession reference
		Sindou	18	2011-2017	2019-2020	ET01 ; ET55A ET17 à ET32
	Léraba	Ouéléni	1	2011-2017	2019-2020	ET42
		Loumana	1	2011-2017	2019-2020	ET43
		Dakoro	1	2011-2017	2019-2020	ET55B
Cascades		Soubakagniedougou	8	2011-2017	2019-2020	ET02 à ET05 ; ET54 ; ET55C ; ET57
	Comoé	Mangodara	7	2011-2017	2019-2020	ET13, ET52 ; ET53 ; ET60 ; ET62 ; ET63; ET67
		Banfora	4	2011-2017	2019-2020	ET06 ; ET14 ; ET15, ET16
		Orodara	7	2011-2017	2019-2020	ET07 à ET12 ; ET69
Haut-Bassins	Kénédougou	Kangala	6	2011-2017	2019-2020	ET37 ; ET45 à ET50

2.2 Physical and morphological characterization of cashew nuts

The weight of cashew nuts was determined using analytical balance (RADWAG) with accuracy of 0.0001g. For each accession, five groups of 30 cashew nuts were randomly selected and weighed. Then the average weight determined. The three main dimensions, namely length, width and thickness of the nuts were measured with a digital caliper (Castorama LR44, Germany) with accuracy of 0.01 mm on 20 nuts from each accession taken at random from the sample

2.3 Indicative parameters of cashew nut quality

Nut count or graining was defined as the number of nuts per kg (Figure 1b) and reflected the average size of the nuts. The quality assessment of the graining was thus determined using the grid (Table 2) proposed by Rongead, (2015). For this analysis the nuts were crushed with secateurs and the separation of the kernel from the shells was done with small knives (Figure 1c and 1d). The kernel yield (KY) is given by the formula:

$$KY\ (\%) = (W2+(W3/2))/W1 * 100 \qquad \text{equation 1,}$$

where,

W1: total weight of the nut sample

W2: weight of healthy kernels (kernels + pellicle) accepted at 100%

W3: weight of kernels + pellicle of the nuts rejected at 50%

The kernel output ratio (KOR) was defined as the amount in pounds (1 Lbs= 0.45359 kg) of good kernel per bag of 80 kg of raw nuts after shelling. It is expressed in Lbs/bag of 80 kg. The KOR was calculated using the following Equation 2 as reported by (Ogunwolu et al., 2016).

$$KOR\ (Lbs/bag\ of\ 80\ kg) = KY/100 * 80/0.45359$$

The KOR was appreciated using the criteria presented in Table 3.

Table 2. Graining quality assessment grid (RONGEAD, 2015).

Amplitude classes	Quality assessment	Description of nuts
<180 nuts	Excellent	Very large nut, sought after quality
[180-190[	Very good	Large nuts, appreciated by industrialists, good KOR
[190-200[	Good	Large nuts, appreciated by processors
[200-210[	Medium	Medium nuts, most common in West Africa
[210-220[	Very average	Medium nuts, more common in West Africa
[220-230[	Just acceptable	Small nuts, not much in demand
>230 nuts	Poor	Small nuts, difficult to process

Table 3. KOR assessment criteria

KOR Category (lbs)	Appreciation
< 42	Extremely poor quality, very hard to process
[42-44[	Very poor quality, hard to process
[44-46[	Poor quality, not very interesting for processors
[46-48[	Acceptable quality
[48-50[	Good quality
[50-52[	Very good quality
[52-54[	Excellent quality
≥ 54	Super quality, rare and highly sought after

2.4. Determination of physicochemical and nutritional characteristics

Moisture, fat, protein, ash and carbohydrate contents were determined. The moisture content of the samples was determined by differential weighing of a 5 g sample before and after oven drying at 105 °C for 12 h according to the French standard NF V 03-707 : 2000. The ash content was determined by incineration of 5 g of sample in a muffle furnace (Nabertherm) at 550 °C for 4 hours, according to the international standard ISO 2171 : 2007. The fat content of the samples was determined by the Soxhlet extraction method according to the international standard ISO 659: 1998 with hexane as solvent. The total protein content was determined by the Kjeldahl method according to the French standard NF V03-050: 1970. The total sugar content of the samples was determined by the spectrophotometric method of determination with sulfuric orcinol. The absorbance of the samples was read at 510 nm with a UNI 002_FR Spectrophotometer I 200 (Montreuil and Spik, 1969). The fibrous residue (FR) or fiber content was determined by the differential method proposed by Gall et al. (2002) by using the formula: FR (%) = [100 - Ash (%) - Protein (%) - Fat (%) - Total sugars (%)]. The energy value (E) was calculated using the coefficients of Atwater and Benedict (1899) according to the following formula: E (Kcal/100g) = [carbohydrate content (%) * 4 (Kcal) + protein content (%) * 4 (Kcal) + fat content (%) * 9 (Kcal)].

Statistical analysis of data

Data were analyzed using descriptive statistics (means, standard deviations). They were then subjected to univariate analysis of variance (ANOVA) or the Kruskal-Wallis test, depending on whether the condition of normality of the quantitative data was met or not. The Fisher test at the 5% level was performed for means comparison. Hierarchical ascending classification was used to study the structuring of variability based on Euclidean distances and aggregation. A discriminant factor analysis was used to describe the identified cashew nut accession groups. Principal component analyses were performed using XLSTAT BASIC + software (Addinsoft, 2016).

3. Results

3.1. Morphological characteristics of cashew nuts

Analysis of variance showed highly significant differences ($P<0.0001$) for weight, size, and kernel count (Table 4). The minimum and maximum values for cashew nut weights were 4.62 ± 0.14 g and 9.06 ± 0.10 g, respectively. For each of nut dimensions (length, width and thickness), the difference between the maximum and minimum values were almost 1 cm (Table 4). The thickness values varied between 1.51 and 2.09 cm, but for the kernel yield, the maximum was the double of the minimum. Less than half of the nuts (41.51%) had weights between 6 and 7 g. Nuts with weights more than 7 g were also important (33.96%) while those with less than 6 g were only 24.53%.

Table 4. Morphological characteristics of cashew nuts from 53 accessions collected in Burkina Faso

Variables	Minimum	Maximum	Mean ± SD	F value
Length (cm)	2.72	3.70	3.15±0.30	7.755*
Width (cm)	2.11	2.89	2.54±0.22	8.110*
Thickness (cm)	1.51	2.09	1.75±0.23	4.929*
Weight (g)	4.62	9.06	6.71±1.13	216.7*
Kernel yield (%)	19.75c	34.28	28.38±2.69	1728.3*
Variables		**Modalities**		**Percentage**
		4≤w≤6		24.53%
Nut weight (g)		6<w<7		41.51%
		w>7		33.96%

F-values and level of significance from One-way Analysis of Variance (ANOVA) comparing cashew nuts characteristics; n = 53.*p < 0.0001, SD=standard deviation

3.2. Evaluation of cashew nuts quality

Values of graining revealed that 96.22% of nuts were of good quality (Figure 1). Further detail showed that 86.79% of the cashew nuts can be classified as excellent, 5.66% as very good and 3.77% as good. The remaining (less than 3.78%), can be classified as fair or just acceptable.

Kernel output ratio quality assessment indicated that the proportion of nuts classified as super quality and excellent quality was similar (71.68%) and was high (Figure 2). The lowest percentages were observed with the undesirable quality, namely extremely poor quality (3.77%) and very poor quality (5.66%).

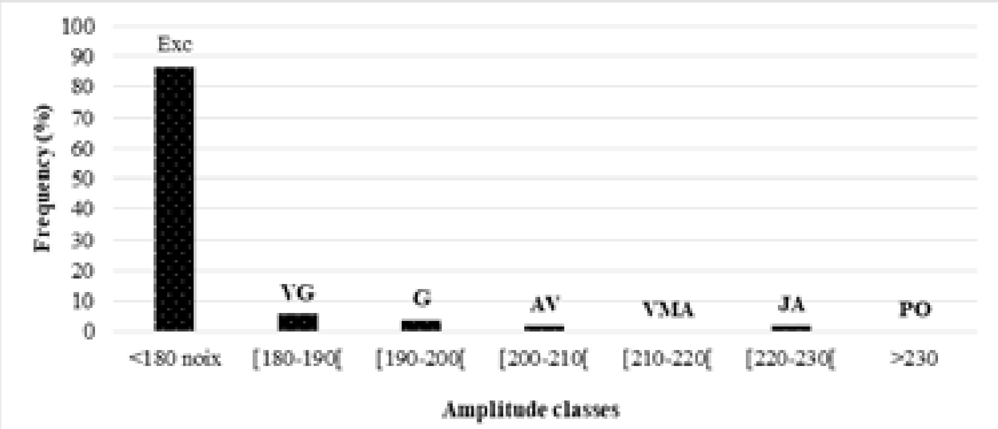


Figure 1. Quality of graining. Exc = Excellent, VG = Very Good, G = Good, AV = Average, VMA = Very Average, JA = Just Acceptable, PO = Poor

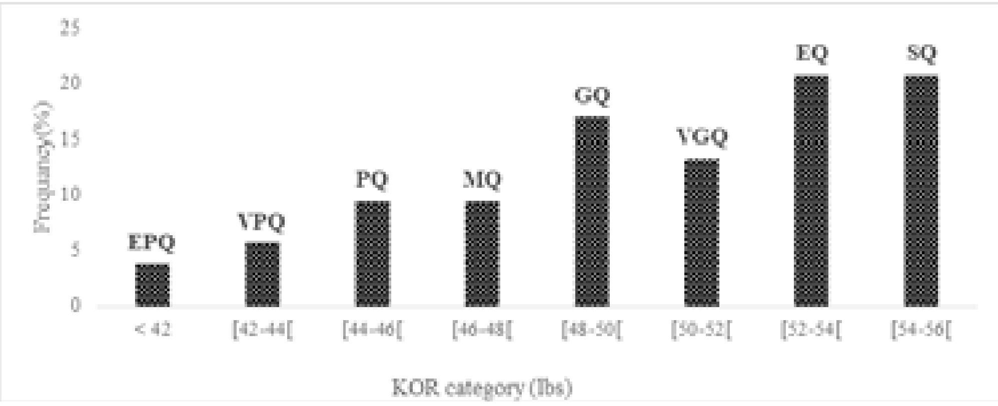


Figure 2 : KOR quality of cashew accessions.

EPQ = Extremely Poor Quality; VPQ = Very Poor Quality; PQ = Poor Quality; MQ = Average Quality; GQ = Good Quality; VGQ = Very Good Quality; EQ = Excellent Quality; SQ = Super Quality

3.3. Organization of nut variability in cashew nuts

From the hierarchical ascending classification (HAC), four groups were identified. The decomposition of the variance showed that the inter-group variability corresponded to 68.83% against 31.17% for the intra-group variability (Table 5).

The graphical representation of half discriminant factor analysis (DFA) design (Figure 3) justified 94.29% of the variability between groups. Group I included 15 accessions out of which 14 originated from Cascades region. This group had the lowest nut weight (5.69 g), highest kernel yield (30.52%), excellent graining (177.53 nuts/kg) and excellent quality of KOR (53.84 lbs). Group II included 12 cashew accessions, all from Cascades region. This group has high kernel yield (30.51%), low nut weights (6.36 g), excellent graining (158.33 nuts/kg) and excellent quality of KOR (53.81 lbs). Group III includes 14 accessions out of which four are from Cascades region. The group GIII showed a better graining than the other three groups with 120.57 nuts/kg, a very high nut weight (8.32 g), good quality of KOR (48.62 lbs), but a low kernel yield (27.57%). Group IV included 12 cashew accessions out of which 9 originated from Cascade region. This group was characterized by a low kernel yield (26.06%), a low nut weights (6.46 g), excellent graining (155.50 nuts/kg) and poor quality of KOR (45.96 lbs).

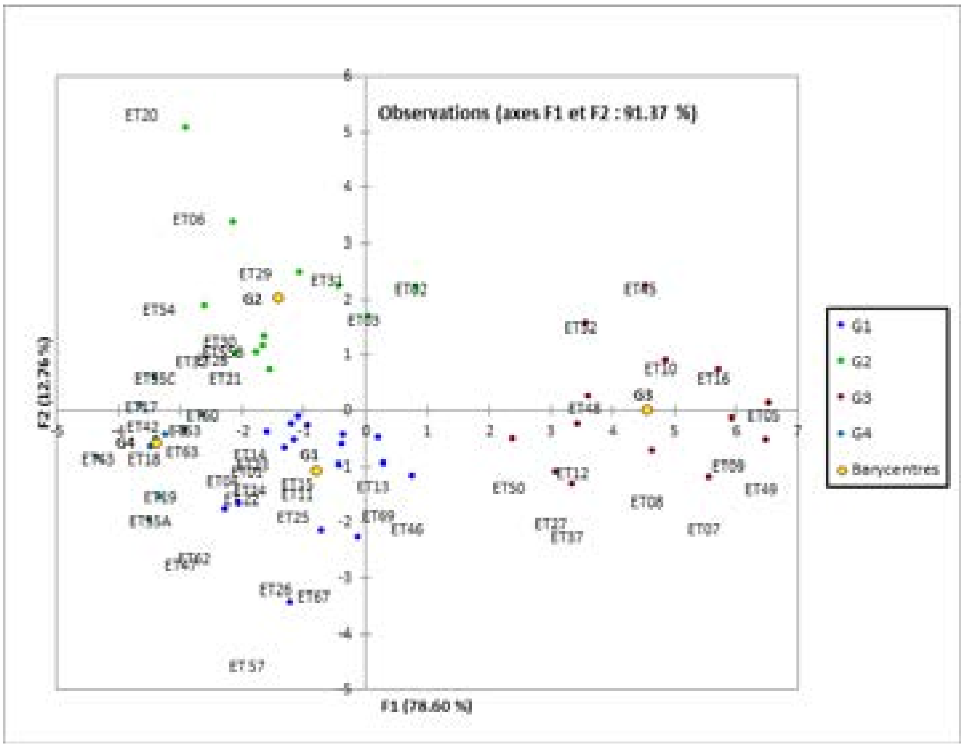


Figure3 : PCA representation of the groups from the HAC in the plane half of the DFA.

Table 5: Morphological and technological characteristics of cashew nuts groups

Variables	Length (cm)	Width (cm)	Thickness (cm)	Graining (nuts/kg)	Weight (g)	Kernel yield (%)	KOR (lbs)
G I	2.93±0.21	2.40±0.09	1.63±0.07	177.53±19.07	5.69±0.58	30.52±1.69	53.84±297
G II	3.19±0.14	2.64±0.11	1.84±0.09	158.33±14.64	6.36±0.55	30.51±2.96	53.81±5.22
G III	3.35±0.09	2.66±0.14	1.84±0.10	120.57±11.49	8.32±0.45	27.57±1.55	48.62±2.74
G IV	3.08±0.18	2.46±0.05	1.69±0.13	155.50±6.62	6.46±0.46	26.06±2.14	45.96±3.77
P- value*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	ns

* Statistics of the Univariate Test of equality of group means. ns: not significant

3.4. Overall physicochemical and nutritional composition of cashew accessions kernels.

There were significant differences (P < 0.001) within the 53 nut kernel samples for all physico-chemical and nutritional parameters (Table 6). Moisture contents were quite low ranging from 3.71 to 6.02 %, with an average of 4.56 ± 0.39%. Ash contents varied from 2.06 to 3.51 % with an average of 2.87 ± 0.27%. Concerning fiber, the diversity is greater within the accessions with contents ranging from 0.66 to 11.89 %, with an average of 4.62 ± 2.52%. Levels of lipids in the nut kernels were ranging from 39.90 to 57.61 % with an average of 50.71± 4.07 %. Protein contents of the kernels ranged from 16.76 to 24.44 % with an average of 20.62 ± 1.58%. The minimum and maximum values for carbohydrate content were 12.20 % and 32.92 % respectively, with an average of 21.18 ± 3.81%. The potential energetic values among accessions ranging from 557.86 to 673.68 Kcal/100g, with an average of 623.59 ±27.00 Kcal/100g.

Table 6. Physicochemical and nutritional characteristics of cashew kernels from Burkina Faso

Characteristics	Moisture (%)	Ash (%)	Cellulose (%)	Fat (%)	Protein (%)	Carbohydrates (%)	Energy value (Kcal/100g)
Number of accessions	53	53	53	53	53	53	53
Mean ± SD	4.59 ± 0.39	2.87 ± 0.27	4.61 ± 2.52	50.71 ± 4.07	20.62 ± 1.58	21.18 ± 3.81	623.59 ±27.00
Minimum value	3.71	2.06	0.66	39.90	16.76	12.20	557.86
Maximum value	6.02	3.51	11.89	57.61	24.44	32.92	673.68
Cv (%)	8.55	9.41	54.66	8.03	7.66	17.99	4.33
P- value*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

SD=standard deviation

3.5. Variability within cashew accessions based on physicochemical and nutritional characteristics of the kernels.

The HAC or dendrogram carried out on the 53 samples of cashew accessions also covered seven variables : moisture, ash, fat, protein, cellulose, carbohydrate, energy value (Figure 4). The results of the AHCrevealed a structuring of the variability of the accessions into three distinct groups. The variance decomposition shows that the inter-group variability corresponds to 82% against 18% for the intra-group variability. Comparison of the group means for the different variables in the DFA revealed highly significant differences for almost all variables with probability values (two-sided P-value) between 0.0001 and 0.008 (Table 3). The graphical representation of the half design of the DFA which explains 100% of the total variability among groups (Figure 5) together with the group means from the AHC shows a characterization of the groups as follows:

Group I composed of 17 accessions, with 32.07% of the total made up of cashew accessions whose kernels have high fat (54.99 ± 1.51% DM (Dry matter)) and energy (648.54 ± 11.83 Kcal/100g), average protein (20.44 ± 1.78% DM), low carbohydrate (17.96 ± 2.39% DM), ash (2.76 ± 0.19% DM) and cellulose (3.84 ± 1.57% DM) contents. This group includes accessions from the two regions (Cascades and Haut Bassins) and distributed in eight departments as follows: 7 accessions from Sindou, 3 from Mangodara, 2 from Banfora, 1 from Ouéléni 2, from Orodara, 2 from Kangala. Only the average protein content was comparable to that of the other groups, i.e. 20.44 ± 1.78% compared to 20.34 ± 1.58% for group II and 20.98 ± 1.23% for group III.

Group II consisted of 16 accessions, with 30.18% of the cashew accessions studied, from the two regions (Cascades and Haut Bassins), including 5 from the department of Sindou, 3 from Soubakagniedougou, 2 from Banfora, 1 from Mangodara, 1 from Loumana, 3 from Orodara and 1 from Kangala. The cashew accessions in this group are opposite to those in group I and were characterised by high carbohydrate (23.61 ± 4.16% DM) and cellulose (7.33 ± 2.44% DM) contents, and lower lipid (45.80 ± 2.21% DM) and energy (588.00 ± 13.09 Kcal/100g) contents. Their protein contents were comparable to that of the other two groups.

Group III is made up of 20 accessions, with 37.73%, spread over two regions (Cascades and Haut Bassins), including seven from Sindou, three from Soubakagniedougou, three from Mangodara, one from Dakoro, two from Orodara and four from Kangala. The accessions in this group are characterized by high ash content (2.94 ± 0.21% DM), average lipid content (50.99 ± 1.68% DM), energy content (630.86 ± 8.15% DM), protein content (20.98 ± 1.23% DM) and carbohydrate content (21.99 ± 2.21% DM), but very low cellulose content (3.09 ± 1.13% DM), which is lower than that of Group I accessions.

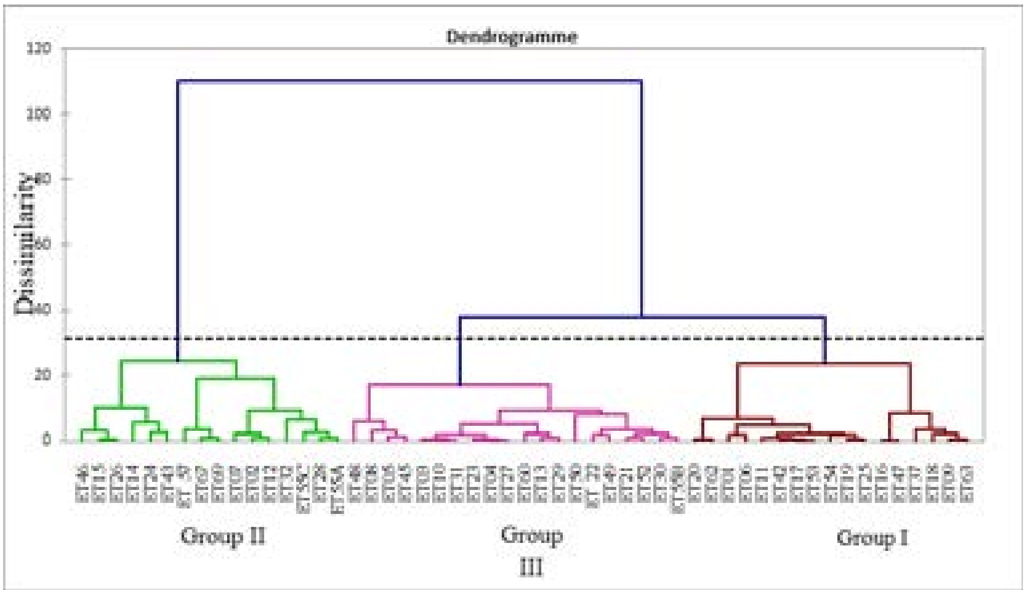


Figure 4 : Ascending Hierarchical Classification (AHC) of the 53 accessions according to Ward's aggregation criteria.

Table 7. Nutritional performance of cashew nut accession groups

Variables	Moisture (%)	Ash (%)	Cellulose (%)	Fat (%)	Protein (%)	Carbohydrates (%)	Energy value Kcal/100g
G II	4.59 ± 0.31	2.91 ± 0.37	7.33 ± 2.44	45.80 ± 2.21	20.34 ± 1.58	23.61 ± 4.16	588.00 ± 13.09
G III	4.77 ± 0.43	2.94 ± 0.21	3.09 ± 1.13	50.99 ± 1.68	20.98 ± 1.23	21.99 ± 2.21	630.86 ± 8.15
P- value*	0.008	ns	<0.0001	<0.0001	ns	<0.0001	<0.0001

P- value* 0.008 ns <0.0001 <0.0001 ns <0.0001 <0.0001

* Statistics of the Univariate Test of equality of group means. ns: not significant

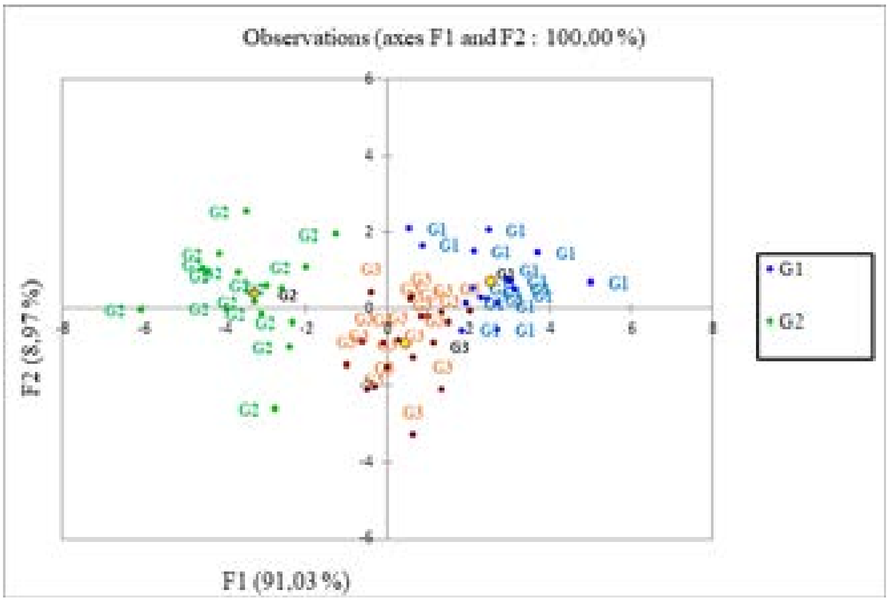


Figure 5 : Expression of nutritional diversity of cashew accessions

4. Discussion

In the present study the nuts of cashew accessions from the western region of Burkina Faso show morphological variability. The overall weight of cashew nuts was similar to that of Côte d'Ivoire (Stéphane et al., 2020) and Benin (Sika et al., 2015; Zoumarou-Wallis et al., 2016). Among the 53 cashew accessions evaluated, 33.96% of the nuts had a high weight according to an international classification (IBPGR, 1986), whose threshold for this category is 7 to 9 g compare to 24.53% that had weight between 4 and 6 g. Thus, most of the nuts have a weight greater than 6 g and are therefore acceptable on the international market. The length and width values are in a comparable range to previous data from Benin (Lautié et al., 2001) and Côte d'Ivoire (Stéphane et al., 2020). However, they are higher than those reported by Sika et al., (2015) with means of 2.37 cm and 1.18 cm for length and width, respectively. On the other hand, the lengths of Benin nuts reported by Zoumarou-Wallis et al., (2016) are higher than ours. As with most plants, optimal growth depends on soil type and rainfall. The differences found could be related to the agropedoclimatic characteristics of the site (Nortcliff and Gregory, 2013 ; Soro, 2012 ; Bello et al., 2017). Studies conducted in different countries such as India (Venugopal and Khader, 1991) and in Bénin (Balogoun et al., 2016) revealed that well-distributed rainfall during the growth and pre-flowering phase favors better cashew nut yield. Nut yield is optimal when temperatures are between 15 and 35 °C, rainfall is above 400 mm, and elevation is at least 2,000 m above sea level (Aliyu and Awopetu, 2007). In addition, deep, well-drained forest brown soils or lateritic soils with high water holding capacity and rich in organic matter seem to be an ideal soil type for better cashew growth and productivity. Eroded laterites and coastal sands seem to be poor soil types (Venugopal and Khader, 1991) and thus not very suitable for cashew cultivation.

Regarding kernel yield, previous studies reported little variation in their collections, ranging from 27.85% to 30.45% in Burkina Faso (Tarpaga et al., 2020), 26.32 to 30.74% in Bengal (Horea et al., 2015) and 24.5 to 32.4% in India (Jena et al., 2016). These values are included in the wider range (19.75 - 34.28%) observed in our study.

The morphological quality assessment of the nuts revealed that most of the nuts were excellent with large nuts (<180 nuts/kg) like data found in Benin (100 -200 nuts/kg) (Ndiaye et al., 2020). The graining in the present study is better quality than the standard of the Economic Community of West African States (ECOWAS) (200 to 250 nuts/kg). The KOR is higher than 50 lbs for 54.70% of the nuts. According to the joint standard of UN member states setting the minimum conditions to sell cashew nuts in the international market, a good KOR should be higher than 50 lbs. The results of the present study are in partial agreement with those reported in different regions in Senegal where average KOR was 50.7 lbs for the Ziguinchor, 50.9 lbs for Sédhiou and 49 lbs for Kolda (Ndiaye et al., 2020). Previous study by Dahiya, (2016) pointed out a low competitiveness of the nut in Africa. Indeed, Nigeria has KOR of 46-48 lbs, Ghana 44-48 lbs, Tanzania 45-52 lbs and Côte d'Ivoire 48-52 lbs while Asian countries namely India and Vietnam both have KOR of 50-56 lbs. However, most of the cashew nuts in this study have a higher KOR than other African countries. The good KOR of these nuts indicated the efficiency of the ongoing selection process and the favorable conditions for the development of cashew trees.

The DFA and HAC allowed a division of the 53 cashew accessions into four groups. The discriminant parameters were mainly weight, graining, kernel yield and KOR. According to the selection criteria, the quality of nuts produced is assessed by two parameters, namely weight of nuts greater than 6 g and kernel yield greater than 25% (Masawe, 2010). The morphological performance of cashew nuts of group II, III and IV are in accordance with the thresholds previously set (Masawe, 2010). Regarding nut characterization of cashew accessions, group IV has the lowest kernel yield. The nuts of groups I and II characterized by kernel yield of 30.51% and 30.52% were similar and correspond to groups II and V for similar study in Burkina Faso (Tarpaga et al., 2020). In addition, the nuts in these groups showed excellent KOR. The group III is potential good seeds for obtaining good parents to produce high weight nuts.

The overall nutritional composition, the study revealed that the different cashew accessions have high nutritional potential. The overall composition found in cashew kernels were comparable to the values reported by Rico et al. (2016) and De Oliveira Sousa et al. (2011), respectively on 11 cashew samples from different origins and on Brazilian cashews. In addition, higher lipid contents (66.21 ± 7.87%) were reported on nine cashew samples from Indonesia by (Trox et al., 2010).

Although lipids represent the major constituent of cashew kernels, carbohydrates were the second major constituent of kernels with contents close to those of proteins. Moisture contents obtained in this study were lower than those reported by Aremu et al. (2006) which was 5.7

± 0.2%. However, they are in line with the standard specifications that recommend cashew nuts moisture content of less than 5% (CEE-ONU, 2012). Interestingly, cashews with low moisture content (<5%) could have the advantage of being stored for longer periods of time without microbial growth or changes in undesirable biochemical compounds (Venkatachalan and Sathe, 2006). The average ash values are also comparable to those reported by Adouko et al. (2016) with cashew nuts from Côte d'Ivoire.

Our results also show that the average cellulose content obtained, 4.61 ± 2.52% is higher than that reported by Aremu et al. (2006), De Oliveira Sousa et al. (2011) and Rico et al. (2016) with respective values of 1.2 ± 0.3%, 3.92 ± 0.05% and 3.6 ± 0.2%. The consumption of cashew kernels with high cellulose content could facilitate digestion and prevent constipation which is the cause of some diseases such as hemorrhoids, colon cancer, appendicitis, etc. (Adouko et al. 2016).

In terms of analysis of variability within the nut samples of cashew accessions, univariate analyses including HAC and DFA identified the main discriminant parameters of lipids, protein, fiber, carbohydrates and energy value respectively. The 53 cashew accessions were classified into three homogeneous groups consisting of accessions with high nutritional potential, which could be used in varietal selection programs.

Group I accessions are particularly rich in lipids and energy, low in carbohydrates and cellulose, and of average protein content. From a nutritional point of view, this group contains the best accessions that can be valorized by breeding programs and that could find many uses in the agri-food industry and especially in programs for the formulation of energy foods to fight malnutrition. Given the high number of accessions in this group, it is possible that there are duplicates and that there is a need for further knowledge on other physicochemical and nutritional parameters. As for the accessions in group II, they are less interesting than the accessions in groups I and III, due to their low lipid and energy content and their high carbohydrate and cellulose content. These accessions with low nutritional potential could be used as food products and for the development of dietary foods. Group III accessions also showed interesting nutritional potential, although lower than those in Group I.

The cross-analysis of agronomically, nutritionally and commercially performing cashew accessions led to a selection of the best performing accessions, of which there were 35. The accessions ET01, ET03, ET04, ET05, ET06, ET08, ET09, ET10, ET11, ET13, ET16, ET17, ET18, ET20, ET21, ET22, ET23, ET25, ET27, ET29, ET30, ET31, ET37, ET42, ET45, ET47, ET48, ET50, ET52, ET53, ET54, ET55B, ET60, ET62, and ET63 were found to have simultaneous agronomic, nutritional, and commercial performance.

5. Conclusion

This study constitutes a step towards the identification of efficient cashew varieties for a more profitable production and the obtaining of competitive nuts in Burkina Faso. Indeed, this work has allowed the identification of 35 accessions out of 53 accessions that present not only interesting agronomic characteristics in the interest of creating high yield plantations with nuts that have an important socio-economic interest on the export market, but also present a high nutritional potential that is interesting for the food industry or nutritional formulation programs.

Acknowledgements

The authors would like to thank the Institut de l'Environnement et de Recherche Agricole (Station de Recherche de Farako-Bâ) for providing us with the samples. The authors would like to thank the Upssala University for funding this research through ISP/IPICS/RABIOTECH, upssala university project at UJKZ, Thanks are also due to the Joseph KI-ZERBO University and the Department of Food Technology (DTA) for their multi-faceted support for this study.

References

Adouko, O. A. A., Traoré, S., Agbo, E. A., & Kouakou, B. (2016). Functional Properties and in vitro Digestibility of Cashew Nut Flour. Journal of Food and Nutrition Research, Vol. 4, 2016, Pages 282-288, 4(5), 282–288. https://doi.org/10.12691/JFNR-4-5-3

Aliyu, O. M., & Awopetu, J. A. (2007). Assessment of genetic diversity in three populations of cashew (Anacardium occidentale L.) using protein-isoenzyme-electrophoretic analysis. Genet Resour Crop Evol., 54, 1489 – 1497. https://doi.org/10.1007/s10722-006-9138-9.

Aliyu, O. M., & Awopetu, J. A. (2011). Variability Study on Nut Size and Number Trade-Off Identify a Threshold Level for Optimum Yield in Cashew (Anacardium occidentale L.). International Journal of Fruit Science, 11, 342–363. https://doi.org/DOI: 10.1080/15538362.2011.630297

Aremu, M. O., Olonisakin, A., Bako, D. A., & Madu, P. C. (2006). Compositional studies and physicochemical characteristics of cashew nut (*Anarcadium occidentale*) flour. Pakistan Journal Of Nutrition, 5(4), 328–333.

Atwater, W.O., Benedict, F.G., Smith, A.W., Bryant, A.P. and Bryant, M.S. (1899) Experiments on the Metabolism of Matter and Energy in the Human Body. Rev. ed. Washington, Govt. Print. Off.

Balogoun, I., Ahoton, E. L., Saïdou, A., Bello, O. D., Ezin, V., & et al. (2016). Effect of Climatic Factors on Cashew (Anacardium occidentale L.) Productivity in Benin (West Africa). J Earth Sci Clim Change., 7, 1. https://doi.org/http://dx.doi.org/10.4172/2157-7617.1000329.

Bello, D. O., Ahoton, L. E., Saidou, A., Akponikpe, I. P. B., Va, E., Balogoun, I., & Aho, N. (2017). Climate change and cashew (Anacardium occidentale L.) productivity in Benin (West Africa): perceptions and endogenous measures of adaptation. Int. J. B Iol. Chem. Sci., 11, 924 – 946.

CEE-ONU. (2012). NORME CEE-ONU DDP-16 concernant la commercialisation et le controle de la qualité commerciale des pommes séchées (p. 7).

Dahiya, S. (2016). Transformation compétitive du cajou en Afrique – Innovations. Festival et Expo mondiaux sur le cajou organisé par l'ACA en 2016. https://www.africancashewalliance.com/sites/default/files/sunil_dahiyaaca_fr.pdf(2016) (Consulté le 31/03/2021).

DDP. (2002). Norme de CEE-ONU DDP-01, Concernant la commercialisation et le contrôle de la qualité commerciale des noix en coque. Edition (p. 11).

De Oliveira Sousa, A. G., Fernandes, D. C., Alves, A. M., de Freitas, J. B., & Naves, M. M. V. (2011). Nutritional quality and protein value of exotic almonds and nut from the Brazilian Savanna compared to peanut. Food Research International, 44(7), 2319–2325. https://doi.org/10.1016/j.foodres.2011.02.013

Dembele, Y. (2010). CARTOGRAPHIE DES ZONES SOCIO-RURALES Burkina Faso (p. 70).

FAOSTAT. (2019). Food and Agricultural Organization of the United Nations Statistics Division.

Gall, M., Montagne, L., Jaguelin-Peyraud, Y., Pasquier, A. and Gaudre, D. (2002) International Table of Glycemic Index and Glycemic Load Values, American Journal of Clinical Nutrition, 76, 5-56.

Hiema, F. (2011). État des lieux des organisations des acteurs de la filière anacarde dans les régions des Hauts-Bassins et des Cascades au Burkina Faso. GIZ. PDA. MAH. (p. 41).

Horea, J. K., Murmu, D. K., Hattopadhyay, N., & Alam, K. (2015). Evaluation of Cashew Germplasms in West Bengal. In Acta Hort., 1080, 135-142. https://doi.org/10.17660/ActaHortic.2015.1080.15.

IBPGR. (1986). (International Board for Plant Genetic Resource), Descriptors for cashew (Anacardium occidentale L.). Rome, Italy. (p. 33).

INSD. (2020). (Institut national de la statistique et de la démographie). Annuaire statistique 2019. (p. 335).

Jena, R. C., Samal, K. C., Pal, A. A., Das, B. K., & Chand, P. K. (2016). Genetic diversity among some promising Indian local selections and hybrids of cashew nut based on morphometric and molecular markers. International Journal of Fruit Science, 16, 69–93. https://doi.org/http://dx.doi.org/10.1080/15538362.2015.1046321.

Kumar, S., & Sigh, S. (2014). Variability assessment of seed traits in Jatropha curcas L. for improvement of oil yield. International Journal of Genetics and Molecular Biology, 6(1), 8–15.

Lautié, E., Dornier, M., Filho, M. D. S., & Reynes, M. (2001). Les produits de l'anacardier : caractéristiques, voies de valorisation et marchés. Article de Synthèse, 56(4), 235–248.

Masawe, P. (2010). Consultancy Report on Cashew Improvement Programme for Selected West African Countries (Benin, Burkina and Côte d'Ivoire), GIZ/iCA, Accra.

Montreuil J, Spik G (1969). Microdosage de sucres : Méthodes colorimétriques de dosage des sucres totaux. Faculté des Sciences, Université de Lille France.

Ndiaye, S., Charahabil, M. M., & Diatta, M. (2020). Evaluation De La Qualité Des Noix Brutes D'anacarde En Casamance (Sénégal). European Scientific Journal ESJ, 16(6), 375–395. https://doi.org/10.19044/esj.2020.v16n6p374

Nortcliff, S., & Gregory, P. J. (2013). The historical development of studies on soil–plant interactions. Soil Conditions and Plant Growth. (p. 21).

Ogunwolu, S. O., Yahaya, L. E., Mokwunye, F. C., Ogunjobi, M. A. K., & Olalekan-Adeniran, M. A. (2016). Evaluation of Quality of Raw Cashew (Anacardium occidentale, L) Nut from Major Cashew Producing Areas of Nigeria. American Journal of Food Science and Technology., 4, 178–181.

Rico, R., Bulló, M., & Salas-Salvadó, J. (2016). Nutritional composition of raw fresh cashew (Anacardium occidentale L.) kernels from different origin. Food Science and Nutrition, 4(2), 329–338. https://doi.org/10.1002/fsn3.294

RONGEAD. (2015). The African cashew sector in 2015 – General trends and country profile. Ouagadougou – RONGEAD & iCA. (p. 37).

Sika, K. C., Adoukonou-Sagbadja, H., Ahoton, L. E., Adebo, I., Adigoun, F. A., Saidou, A., Kotchoni, S. O., Ahanchede, A., & Baba-Moussa, L. (2015). Indigenous knowledge and traditional management of cashew (Anacardium occidentale L.) genetic resources in Benin. J. Exp. Biol. Agric. Sci, 1, 375–382. https://doi.org/https://doi.org/10.4172/2376-0354.1000153.

Soro, D. (2012). Couplage de procédés membranaires pour la clarification et la concentration du jus de pomme de cajou : Performances et impacts sur la qualité des produits (p. 156).

Stéphane, K. Y., Halbin, K. J., & Charlemagne, N. (2020). Comparative Study of Physical Properties of Cashew Nuts from Three Main Production Areas in Côte d'Ivoire. Agricultural Sciences, 11, 1232–1249.

Tarpaga, W. V., Bourgou, L., Guira, M., & Rouamba, A. (2020). Caractérisation agro morphologique d ' anacardie rs (Anacardium occidentale L .) en sélection pour le haut rendement et la qualité supérieure de noix brute au Burkina Faso. International Journal of Biological and Chemical Sciences, 14(December), 3188–3199.

Trox, J., Vadivel, V., Vetter, W., Stuetz, W., Scherbaum, V., Gola, U., & Al., E. (2010). Bioactive compounds in cashew nut (Anacardium occidentale L.) kernels: effect of different shelling methods. J. Agric. Food Chem., 58, 5341–5346.

Venkatachalan, M., & Sathe, S. K. (2006). Chemical composition of selected edible nut seeds. Journal of Agricultural and Food Chemistry, 54(13), 4705–4714. https://doi.org/10.1021/jf0606959

Venugopal, K., & Khader, K. B. A. (1991). Effect of soil and climate on the productivity of cashew. Ind. Cashew J., 20, 19–24.

Wallis, N. Z., Bagnan, M. A., Akossou, A. Y. J., & Kanlindogbe, C. B. (2017). Caractérisation morphologique d'une collection de fruits d'anacardier provenant de la commune de Parakou (Bénin). International Journal of Biological and Chemical Sciences, 10(6), 2413. https://doi.org/10.4314/ijbcs.v10i6.1

Zoumarou-Wallis, N. Z., Bagnan, M. A., Akossou, A. Y. J., & Kanlindogbe, C. B. (2016). Caractérisation morphologique d'une collection de fruits d'anacardier provenant de la commune de Parakou (Bénin). International Journal of Biological and Chemical Sciences., 10, 2413–2422. https://doi.org/https://doi.org/10.4314/ijbcs.v10i6.1.

POTENTIAL OF DEFATTED CASHEW KERNEL MEAL AS A VIABLE REPLACEMENT FOR GROUNDNUT CAKE IN BROILER CHICKEN DIET

Taiwo K. Ojediran[1*], Olayemi C. Olagoke and I. Adewale Emiola[2]

[1]Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Techhnology, Ogbomoso, Nigeria, tkojediran@lautech.edu.ng
[2]Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Techhnology, Ogbomoso, Nigeria, iaemiola@lautech.edu.ng

Abstract

This experiment investigated the use of Defatted Cashew Kernel Meal (DCKM) as a replacement for groundnut cake (GNC) in the diet of broiler chicken in a 35-day feeding trial. One hundred and fifty 1-d old chicks were randomly assigned into five experimental groups of thirty birds each. Each group was further subdivided into three replicates of ten birds in a completely randomized design. Five dietary treatments were formulated such that Maize-groundnut meal basal diet served as the control (diet 1). The DCKM was used to replace GNC meal at 10%, 20%, 30% and 40% for diets 2, 3, 4, and 5, respectively. All diets were formulated to meet or exceed the nutrient requirement of broiler chicks. Result of chemical analysis of DCKM showed that it contained 27.59% crude protein, 31.84% ether extract, 3.24% crude fibre, 3.35% Ash, 24.92% nitrogen free extract and 4086.07 KCal/kg metabolizable energy. Data collected were subjected to One Way Analysis of Variance (ANOVA). Treatment means were separated using Duncan Multiple Range Test. The use of defatted cashew kernel meal as a replacement for GNC reduced the cost of production by up to 7-8.50%. There were significant differences ($p<0.05$) in growth parameters at the finisher phase unlike the starter phase ($p>0.05$). The final weight, average daily feed intake, daily gain and feed conversion ratio were significantly influenced at the finisher phase. At the starter phase, the feed cost per kg reduced linearly from diet 1-5 ($p<0.05$). Birds fed diet 1 had a significantly higher feed cost while those fed diet 5 had the least ($p<0.05$). At the finisher phase, birds fed diet 5 had the highest income per kg weight gain ($p<0.05$). However, the profit was highest for birds offered diet 5 while those fed other diets were lower ($p<0.05$) at both phases. Broiler chicken could tolerate up to 40% defatted cashew kernel meal as a replacement for GNC because of the growth performance, reduced cost of production and increased profit margin. Further research could look into the use of cashew kernel meal up to 100% replacement for GNC.

Keywords: *Broiler; Chicken; Cashew kernel meal; Groundnut cake*

1.0 Introduction

Food security is threatened by climate change which has adversely affected grain production. Ojediran et al., (2021) stressed that in southwestern states of Nigeria, rainfall does not stabilize until late May unlike around April in the past and this has narrowed the availability of maize, soybean and groundnut which are convectional feedstuffs prompting price hike owing to stiff competition between man and his livestock, especially the monogastric animals such as pigs and poultry. There is therefore the need to investigate non-conventional feedstuffs such as agro-industrial by-products that could be used as replacement for the expensive soybean meal and groundnut cake meal. Drought-resistant crops such as Cashew (Anacardium occidentale) kernel meal could come to the rescue.

Cashew tree thrives in the tropical region and has gained a status as an important economic crop (KGF, 2011), because of the nut which has become an important industrial and export commodity in many parts of Africa, Asia and South America (Akinhanmi et al., 2008). Nigeria lost its place to Cote d'Ivoire as Africa's leading producer of the nuts (FAO, 2015; Heuzé et al. 2017) since 2010 (Adesanya et al. 2021). Nevertheless, cashew nut processing plants are growing in numbers, especially in exporting countries of Africa, Asia and Latin America (Akinhanmi et al. 2008). During processing, unsuitable portions of the kernel, unfit for export owing to damages are discarded and depending on quality, are estimated to be as high as 30% (Akande et al. 2015) of the total kernel processed. Ojewola et al. (2004), FAO (2013) and Akande et al. (2015) reported these discards were suitable as component of animal feed. The cost of feed in a livestock enterprise could be as high as between 65% to 78%. These expenses unilaterally impact the profit of chicken producers. Therefore, alternative sources of feedstuff are important (Choi et al. 2015). The cost of maize grain, soybean meal and groundnut cake, which are significant in chicken feed, increased because of considerable demand for food and bio-fuel (De Gorter et al. 2013). The expansion in cashew production, global output and demand from various countries are a proof that the kernels will be available as a feasible livestock feed ingredient (FAO 2013). However, the use of the processed kernel in livestock diet is not widely researched. Thus, there is research deficit using cashew kernel because deserved awareness has not been given to it.

2.0 Materials and methods

2.1 Experimental site

The experiment was carried out at the Teaching and Research Farm, Poultry Unit, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria located in the derived savannah zone on Lat. 18° 15' N.; Long. 4° 5' E. and between 300-600m above the sea level.

2.2 Procurement and preparation of test ingredient

The cashew kernel meal was procured from Valency Cashew Nut Processing Company Limited, Ewu, Ogun state and transported to the experimental site. Extraneous materials were removed from the procured cashew kernel meal. The cashew kernel was milled into a paste. The paste was collected into a cheese cloth and subjected to hydraulic press to strain out the oil (Table 3). Finally, the cake obtained was air dried and incorporated into the diets treatments.

2.3 Experimental birds

One hundred and fifty (150) 1- d old broiler chicks of Cobb-500 strain were procured from a reputable hatchery in Ibadan, Oyo state. The chicks were raised in an intensive (deep litter) system. The birds were randomly divided into five (5) groups of thirty (30) birds per group in a completely randomized design. Each group was further divided into three (3) replicates of ten (10) birds each. Feed and water were supplied ad-libitum and other standard operating procedures were followed. The experiment lasted for a period of five (5) weeks.

2.4 Experimental diet

Five (5) experimental diets were formulated (Table 1 & 2), such that maize-GNC meal basal diet served as the control (D1). The groundnut cake in the control diet was replaced by DCKM at 10, 20, 30 and 40% in diets 2, 3, 4 and 5, respectively. Diets were formulated to be isocaloric and isonitrogenous. The diets were allocated to each group of birds in a completely randomized design.

Table 1: Gross formulation of the starter diets.

Ingredients	D1 (0%)	D2 (10%)	D3 (20%)	D4 (30%)	D5 (40%)
Maize	45.00	45.00	45.00	45.00	45.00
GNC	33.00	29.70	26.40	23.10	19.80
DCKM	0.00	3.30	6.60	9.90	13.20
Corn bran	10.00	10.00	10.00	10.00	10.00
Fish meal	4.00	4.00	4.00	4.00	4.00
Methionine	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25
Bone meal	4.00	4.00	4.00	4.00	4.00
Limestone	3.00	3.00	3.00	3.00	3.00
Salt	0.25	0.25	0.25	0.25	0.25
Vit/Min premix#	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00
Calculated nutrient					
Crude protein	23.11	22.56	22.02	21.48	20.94
ME (kcal/kg)	2786.56	2773.66	2804.37	2855.39	2906.41
Crude fibre	3.43	3.37	3.31	3.26	3.19
Ether extract	4.51	5.36	6.54	7.07	7.92
Price (NGN)	294.39	288.12	281.89	275.58	269.31

#2.5 kg Premix used supplied vitamin A, 12,500000iv: vitamin D, 2500000iv; vitamin E,40,000mg; vitamin K3,2000mg; vitamin B1, 3000mg; vitamin B2 5500mg Niacin, 55000mg; calcium pantothenate,11500mg vitamin B6, 5000mg; vitamin B12, 25mg; Folic acid,1000mg; biotin, 80mg; choline chloride 500000mg; manganese, 120000mg; Iron 100,000mg; zinc, 80000mg; copper 8500mg; iodine 1500mg cobalt 3000mg; selenium 120mg and anti-oxidant 120,000mg.

GNC = Groundnut cake, DCKM = defatted cashew kernel meal, ME = metabolizable energy

GNC costs NGN340/kg while DCKM costs NGN200/kg

Table 2: Gross formulation of the finisher diets.

Ingredients	D1 (0%)	D2 (10%)	D3 (20%)	D4 (30%)	D5 (40%)
Maize	54.00	54.00	54.00	54.00	54.00
GNC	23.00	20.70	18.40	16.10	13.80
DCKM	0.00	2.30	4.60	6.90	9.20
Corn bran	15.00	15.00	15.00	15.00	15.00
Fish meal	2.00	2.00	2.00	2.00	2.00
Methionine	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25
Bone meal	2.00	2.00	2.00	2.00	2.00
Limestone	3.00	3.00	3.00	3.00	3.00
Salt	0.25	0.25	0.25	0.25	0.25
Vit/Min premix#	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00

Calculated nutrient					
Crude protein	18.97	18.59	18.21	17.84	17.46
ME (kcal/kg)	2826.56	2862.12	2897.67	2933.24	2968.80
Crude fibre	3.53	3.48	3.44	3.40	3.36
Ether extract	4.27	4.86	5.45	6.05	6.64
Price (NGN)	247.29	288.12	281.89	275.58	269.31

#2.5 kg Premix used supplied vitamin A, 12,500000iv: vitamin D, 2500000iv; vitamin E, 40,000mg; vitamin K3,0000mg; vitamin B1, 3000mg; vitamin B2 5500mg Niacin, 55000mg; calcium pantothenate,11500mg vitamin B6, 5000mg; vitamin B12, 25mg; Folic acid,1000mg; biotin, 75mg; choline chloride 500000mg; manganese, 120000mg; Iron 100,000mg; zinc, 80000mg; copper 8500mg; iodine 1500mg cobalt 3000mg; selenium 120mg and anti-oxidant 120,000mg

2.5 Chemical Analyses

Proximate analyses of the test materials were carried out using the standard procedures of the AOAC (2012). While the metabolizable energy was calculated using the Pauzenga (1985) formula.

2.6 Statistical Analysis

Data obtained were subjected to a one-way analysis of variance using IBM SPSS (version 21). Significant ($P < 0.05$) means among variables were separated using Duncan Multiple Range Test (Duncan, 1955) of the same package.

2.7 Data collection

2.7.1 Growth performance

A known amount of feed was offered daily and the leftovers after 24 hours were weighed. Average feed intake for each day was obtained by the difference between the total feed given and the leftovers. Average feed consumption per bird for the day was calculated by dividing the total weight of feed consumed by the number of birds. Birds in each replicate were weighed on arrival and subsequently weighed at the end of each week. The average body weight per bird was obtained from each replicate by dividing the total body weight in each replicate by the total number of birds in the replicate. The feed conversion ratio was calculated by dividing the weight of feed consumed by the weight gain of the birds.

2.7.2 Economic indices

Economic parameters were calculated as described by Ojediran et al., (2017):

Feed cost/kg = Sum (quantity of each ingredient x unit cost of each ingredient)

$$\text{Feed cost per kg weight gain (NGN)} = \frac{\text{Feed cost x total feed intake (kg)}}{\text{Total weight gain}}$$

$$\text{Income per kg weight gain bird (NGN)} = \frac{\text{Selling price per bird}}{\text{Total weight gain}}$$

Profit per kg weight gain (NGN) = Income per kg weight – feed cost per kg weight gain.

3.0 Results

3.1 Chemical composition

The result of the chemical composition of defatted cashew kernel meal shows that it contained 27.59% crude protein, 31.84% ether extract, 3.24% crude fibre, 3.35% ash and 24.92% nitrogen-free extract (Table 3). The metabolizable energy was 4086.07 kcal/kg.

Table 3 Chemical composition of the defatted cashew kernel meal

Proximate Fraction	Percentage (%)
Dry matter	90.95
Crude protein	27.59
Crude fat (Ether extract)	31.84
Crude fibre	3.24
Ash	3.35
Nitrogen free extract	24.92
Metabolizable energy (kcal/kg)	4086.07

3.2 Growth performance

There were no significant differences (p>0.05) in all the growth parameters examined at the starter phase (Table 4). These include the initial weight, final weight, average daily feed intake, and average daily gain and feed conversion ratio.

At the finisher phase, all the parameters showed significant differences (p<0.05) except the initial weight (Table 5). Birds fed diet 5 (40%) had the highest final weight and was significantly different (p<0.05) from those fed diets 3 and 4 (p > 0.05) while birds fed diets 1 and 2 were comparable. Birds fed diets with DCKM had lower feed intake compared with those fed on the control diet, although only those fed diet 3 was significantly different (p < 0.05) from those fed diet 1. The average daily gain ranged from 48.34g/b to 64.45g/b in diets 3 and 5 respectively (p<0.05). The feed conversion ratio observed was 2.41, 2.60, 2.53, 2.52 and 2.01 for diets 1-5 respectively.

Table 4: Growth performances of broiler chicks fed defatted cashew kernel meal as replacement for groundnut cake (starter phase, weeks 1-3)

Parameters	Control	10%	20%	30%	40%	SEM
Initial wt (g)	42.57	44.03	44.47	43.3	40.47	0.67
Final wt (g)	498.15	498.67	465.83	452.96	456.67	10.59
ADFI (g/d)	50.11	50.82	48.16	50.52	47.76	0.89
ADG (g/d)	21.69	21.65	20.06	19.51	19.81	0.46
FCR	2.31	2.44	2.40	2.59	2.41	0.04

ADFI - average daily feed intake, ADG - average daily gain, FCR - feed conversion ratio, SEM - standard error of mean

Table 5: Growth performances of broiler chicken fed defatted cashew kernel meal as replacement for Groundnut Cake (finisher phase, weeks 4-5)

Parameters	Control	10%	20%	30%	40%	SEM
Initial wt (g)	498.1	496.67	465.83	452.96	456.67	7.36
Final wt (g)	1275.00ab	1191.67ab	1142.59b	1166.67b	1359.72a	27.36
ADFI (g/d)	133.74a	129.07ab	122.30b	128.47ab	129.55ab	2.27
ADG (g/d)	55.49ab	49.64b	48.34b	50.98b	64.45a	2.84
FCR	2.41b	2.60a	2.53b	2.52b	2.01c	0.06

abc Means in a row with different superscripts are significantly different (p < 0.05).

3.3 Economic indices

The feed cost per kg reduced linearly from diet 1-5 during the starter phase (1 – 3 weeks). Diet 1 had a significantly higher feed cost while diet 5 had the least (p<0.05). However, the profit was highest for birds offered diet 5 while those fed other diets were lower (p<0.05) (Table 6).

The feed cost per kg and feed cost per kg weight gain was not significantly different (p>0.05) unlike the income and profit per kg (Table 7). Revenue were NGN1275.00, 1191.00, 141.00, 1166.00 and 1359.00 for birds fed diets 1, 2, 3, 4 and 5 respectively. The profit for birds fed diets 1-4 were not significantly different (p>0.05) but were significantly different from those fed diet 5 which had the highest value.

Table 6 Economic indices of broiler chicks fed defatted cashew kernel meal as replacement for groundnut cake (starter phase, weeks 1-3)

Parameters	Control	10%	20%	30%	40%	SEM
FCR	2.31	2.44	2.40	2.59	2.41	0.03
FC/Kg (NGN)	294.56a	288.12ab	281.89ab	275.58ab	269.31b	3.23
FC/Kg WG (NGN)	680.04	703.01	676.54	713.75	649.04	22.64
IC/Kg WG (NGN)	878.00	879.82	949.31	976.42	961.07	24.51
Profit (NGN)	197.96c	176.80c	272.77b	262.67b	312.04a	25.57

FCR - feed conversion ratio, FC – Feed cost, WG – weight gain, IC – Income, SEM - standard error of mean

Table 7: Economic indices of broiler chicken fed defatted cashew kernel meal as replacement for Groundnut Cake (finisher phase, weeks 4-5)

Parameters	Control	10%	20%	30%	40%	SEM
FCR	2.41b	2.60a	2.53b	2.52b	2.01c	0.06
FC/Kg (NGN)	247.29	242.92	238.55	234.18	229.81	2.74
FC/Kg WG (NGN)	595.97	631.59	603.53	590.13	461.91	26.94
IC/Kg WG(NGN)	1275.00ab	1191.00ab	1142.00b	1166.00ab	1359.00a	30.54
Profit (NGN)	679.03b	559.87b	538.47b	575.87b	897.08a	41.64

abc Means in a row with different superscripts are significantly different ($p < 0.05$).

4.0 Discussion

4.1 Chemical constituents of cashew meal

The result of the proximate composition of defatted cashew kernel meal shows that it contains 27.59% crude protein, 31.84% ether extract, 3.24% crude fibre, 3.35% Ash and 24.92% nitrogen free extract. The metabolizable energy was 4,086.07 kcal/kg. This observation is different from defatted cashew meal reported by Akande et al., (2015) as 35.40% crude protein, 1.05% crude fibre, 5.45% ash, 15.10% ether extract, 34.50% nitrogen free extract and 5,035kcal/kg gross energy. The difference could be attributed to efficiency of defattening (Ojediran et al., 2020). Ojewola et al., (2004) attributed such changes to factors such as processing technicalities. Akande et al., (2015) also reported that groundnut cake had 43.10% crude protein, 6.00% ether extract, 4.30% crude fibre, 5.51% Ash and 31.80% nitrogen free extract. The protein content of the DCKM used was lower than Soybean meal and GNC but higher than palm kernel cake, cassava vinnase (Ojediran et al., 2019; 2020) and biscuit dough (Shittu et al., 2016).

4.2 Growth performance

The non-significant growth parameters examined at starter stage is similar to that of Oddoye et al. (2012) who reported that the inclusion of cashew kernel meal up to 150g/kg in the diet of broiler chickens did not significantly influenced performance. However, this study contradicted that of Ogungbenro et al. (2016) who observed that the average final weight, weight gain, feed intake, protein intake and feed conversion ratio were significantly affected by inclusion of cashew nut meal in the diets of turkey poults. This investigation showed that DCKM was well utilized by the chicks.

Observation on growth parameters at the finisher phase was contrary to the report of Oddoye et al., (2012) who observed a non-significant feed intake, daily gain, feed conversion ratio and final weight. The reduced feed intake across the groups could be attributed to the residual oil in the DCKM because birds eat to meet their energy requirement. Akande et al., (2015) observed that birds fed undefatted cashew kernel meal had reduced feed intake which was attributed to the energy content of the feed which increased with increasing levels of the meal. The birds fed diet 5 in this study had higher daily gain which compare favourable with those fed control diet. This show that the diet were well tolerated up to 40% replacement for GNC. This is also similar to the feed conversion ratio, Ojewola et al., (2004) reported that cashew nut meal is a suitable replacement for soybean meal.

4.3 Economic indices

Economic analyses of treatments showed that the inclusion of DCKM could reduce the cost of feed per kg (Tables 1 & 2). Up to 40% replacement for GNC, the cost of production could be reduced by 7-8.50%. This demonstrates that DCKM is a viable alternative to GNC. The lower feed cost variable is attributable to the lower cost per kg of DCKM when compared to GNC. This result indicated that the inclusion of DCKM reduces the cost of feed and also increases the economy of gain as birds on diet containing DCKM require less money to gain a unit weight (Jaji et al., 2011). The reduced cost of feed as the cashew kernel meal increased proved that it has the potential to reduce the cost of production. This translated into increased profit at both phases especially at 40% replacement level.

5.0 Conclusion

Conclusively, broiler chicken could tolerate up to 40% cashew kernel meal as a replacement for GNC because of the growth performance and reduced cost of production. Further research could look into the use of cashew kernel meal up to 100% replacement for GNC.

Acknowledgements

This research work was supported with fund from STARKINK GLOBAL AND IDEAL LIMITED, Starlink House, 106/108, Apapa-Oshodi Express way, Aswani, Isolo Industrial Estate, Lagos, Nigeria.

References

Adesanya, K.A., Agbola-adedoja, M.O., Adelusi, A.A., Ogunwolu, Q.A., Ugwu, C.A., Alli, M.A. and Akinpelu, A.O. (2021). Opportunities in Nigerian cashew nut value chain. World J. Adv. Res. Rev., 9(1): 168–174.

Akande, T.O., Akinwumi, A.O. and Abegunde, T.O. (2015). Cashew reject meal in diets of laying chickens: nutritional and economic suitability. J. Anim. Sci. Technol., 57: 1–7.

Akinhanmi, T.F., Atasie, V.N. and Akintokun, P.O. (2008). Chemical composition and physicochemical properties of cashew nut (Anacardium occidentale) oil and cashew nut shell liquid. J. Agric. Food. Environ., 2(1): 1–10.

AOAC. (2012). Official methods of analysis (19th ed). Association of Official Analytical Chemists, Arlington, VA.

Choi, H.B., Jeong, J.H., Kim, D.H., Lee, Y., Kwon, H. and Kim, Y.Y. (2015). Influence of rapeseed meal on growth performance, blood profiles, nutrient digestibility and economic benefit of growing-finishing pigs. Asian Australasian Journal of Animal Science, 28: 1345–1353.

De Gorter, H., Drabik, D. and Just, D.R. (2013). Biofuel policies and food grain commodity prices 2006-2012: All boom and no bust? Agbioforum, 16(1): 1–13.

Food and Agriculture Organization (FAO) (2013). Food and Agriculture Organization of the United Nations Statistics division, http://faostat3.fao.org/browse/Q/QC/E.

Food and Agriculture Organization (FAO) (2015). Food and Agriculture Organization of the United Nations, Rome, Italy, pp: 68–70.

Heuzé V., Tran G., Hassoun P., Bastianelli D. and Lebas F. (2017). Cashew (Anacardium occidentale) nuts and by-products. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, http:// www.feedipedia.org/node/56.

KFG (2011). Export potentials for high value crops from Bangladesh; An assessment based on global market analysis, Available at www.kfg.org.bd.../10-project%20code%20.

Oddoye, E.O.K., Agyente-Badu, K. and Johnson, V. (2012). Broiler chicks performance on finisher diets containing different levels of cashew kernels. Agric. Sci. Res. J., 2(4): 154–158.

Ogungbenro, S.D, Bamgbose, A.M, Oso, A.O, Sogunle, M.O, Akinosun, A.A, and Oseni, T.A. (2016).The performance characteristics of poult.fed cashew nut meal-maize offal as partial for maize proceeding of 18th Annual conference of Animal Science Association of Nigeria, pp 242- 245.

Ojediran, T.K., Fasola, M.O., Oladele, T.O., Onipede, T.L. and Emiola, I.A. (2017). Growth performance, flock uniformity and economic indices of broiler chickens fed low crude protein diets supplemented with lysine. Archivos de Zootecnia, 66(256): 543–550.

Ojediran, T.K., Abioye, I.A., Ajayi, A.F., and Emiola, I.A. (2019). Replacement value of cassava vinasse meal for maize on growth performance, haematological parameters and organoleptic properties of Japanese quails (Coturnix japonica). Acta fytotechn et zootechn, 22(1): 7–12.

Ojediran, T.K., Olayiwola, S., Adeyeye, M., Ajayi, A.F. and Emiola, I.A. (2020). Effects of palm kernel meal-based diet with or without enzyme supplementation on growth performance, economic benefits and villi morphometry of weaned Pigs. Pol. J. Natur. Sc., 35(2): 129–139.

Ojediran, T.K., Oyebamiji, O., Areo, E. and Emiola, I.A. (2021). Growth parameters, economic analysis and blood characteristics of weaned pigs fed cashew reject kernel meal. Pol. J. Natur. Sc., 36(2): 131–145.

Ojewola, G.S., Okoye F.C., and Agbakuru, I. (2004). Replacement of cashew nut meal for soybean meal in finishing broiler chickens. Int. J. Poult. Sci., 3: 513–516.

Pauzenga U. (1985). Feeding parent stock. Zootenica International, pp. 22–24.

Shittu, M.D., Ojebiyi, O.O., Ademola, S.G. and Ojediran, T.K. (2016). Replacement value of biscuit dough for maize on performance and nutrient utilization of broiler chickens. International Journal of Science, Environment and Technology. 5(3) 1057 – 1065.

NUTRITIONAL EVALUATION OF DRIED CASHEW APPLE IN BROILER CHICKENS DIETS

Oluwatosin, S. Oyekola[1], Olayemi, C. Olagoke[2],and Isiaka, A. Emiola[3]*

[1]Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria, oyekolaoluwatosinsolomon@gmail.com
[2]Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria, ocolagoke@lautech.edu.ng
[3]Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria, iaemiola@lautech.edu.ng (corresponding author)

Abstract

This study evaluated the response of broiler chickens fed diets containing graded levels of Dried Cashew Apple (DCA) as a replacement for maize supplemented with or without enzyme. Two hundred and ten (210) day-old Ross broiler chick strains were utilised in this experiment that lasted 35 days. A maize-soybean meal-based diet without DCA served as the control diet (T1); diets T2, T3, and T4 contained 10, 20, and 30% DCA without enzyme supplementation, while diets T5, T6, and T7 had 10, 20, and 30% DCA supplemented with an enzyme, respectively. Feed and water were provided ad libitum throughout the period of the experiment. Average Daily Feed Intake (ADFI, g/b/d), Average Daily Gain (ADG, g/b/d), and feed: gain (F/G) ratio was used as a measure of performance. The weight of organs and nutrient digestibility were also determined. Data were analyzed using One Way Analysis of Variance (ANOVA), and significant means were separated using Duncan's multiple range test. The results showed that birds fed diets containing 10% DCA supplemented with or without enzyme (T2 and T5) had the highest ADG ($P < 0.05$) than birds fed the control diet (T1) and 20% DCA supplemented with enzyme (T5). The ADFI and F/G ratio increased with ($P < 0.05$) increasing levels of DCA in the diet. Supplementation with exogenous enzyme significantly ($P < 0.05$) lowered ADFI and F/G in birds fed non-supplemented DCA diets. Nutrient digestibility significantly ($P < 0.05$) increased with increasing levels of DCA up to 20% in the diet, while 30% DCA in the diet resulted in the lowest nutrient digestibility. The addition of exogenous enzymes linearly resulted in improved nutrient digestibility. Birds fed diets containing 10% DCA supplemented with or without enzyme had the highest carcass yield, while birds fed a diet containing 20% DCA with enzyme supplementation had carcass yield comparable to those of birds fed the control diet (T1). This study concluded that DCA could be used to replace maize in the diets of broiler chickens at both starter and finisher phases without any detrimental effect on the performance of broiler chickens, especially when supplemented with exogenous enzymes. Similarly, the environmental pollution resulting from the increasing production of cashew nuts could be solved when livestock farmers are encouraged to incorporate DCA into animal feeds.

Keywords: Broiler; Chicken; Cashew apple meal

1.0 Introduction

The potential of poultry production and most especially broiler production as a tool for poverty alleviation and supply of high-quality protein for the ever-increasing population in most developing countries has not been fully harnessed largely due to inadequate feeding (Ekanemet al., 2016). Broiler chickens are quick-growing animals that can reach market weight within a short time of six to seven weeks. Their short generational interval coupled with the intensive system of production permits high stocking density (Dieumou et al., 2013) which makes broiler production a better business alternative for youths and women who form a significant part of the population of most developing countries including Nigeria. However, the achievement of these lofty potentials is limited by feed insufficiency.

Feed cost accounts for about 70 – 80% of the total cost of livestock production (Durunna et al., 2005). Competition between humans and livestock for the limited food resources produced in developing countries has caused even more scarcity of conventional materials used in feed production. Livestock depends on grains and agro-industrial by-products for the bulk of their feed. In recent times there has been an increase in livestock production, and this, in turn, has caused a significant increase in demand and price of agro-industrial by-products, which ultimately resulted in the overall increase in the cost of production. In an attempt to reduce the increase in the price of feed production, nutritionists often investigate the inclusion of unconventional feed ingredients in animal diets. In some cases, the inclusion of alternative feed ingredients in livestock diets could reduce the cost of feed but is limited by the lack of information on their nutritional value. Cashew apple is a by-product of cashew nut production and possesses a great potential in overcoming the chronic high feed cost mitigating against broiler production. Cashew apple is rich in carbohydrates, vitamins, minerals, amino acids, carotenoids, organic acids, and antioxidants (Antony et al., 2020). The cashew apple is seen as a waste in Nigeria, most of which constitutes a nuisance and poses an environmental pollution threat to mankind. Therefore, cashew apple could be utilized as an alternative feed ingredient in broiler's ration, thereby reducing the cost of feed production and increasing profit margin in broiler chicken production enterprise

However, the full incorporation of alternative feed ingredients in livestock diet is usually hindered by the presence of anti-nutritional factors and bio-availability of nutrients. According to Soltan (2009), this adverse effect can be cushioned by supplementation of the diet with an exogenous enzyme. Due to the action-specific characteristics of most enzymes present in the market, the crude fiber profile and the non-starch polysaccharide (NSP) content of a particular diet will determine the most appropriate choice of exogenous enzyme for the diet (Bedford, 2000; Ani et al., 2012). Thus, it is imperative to develop ways to fully harness the great yield of cashew apple, and prevent wastage, and environmental pollution by processing it for utilization in animal feed. Therefore, this study aims to address the incorporation of dried cashew apple (DCA) with or without enzyme supplementation into broiler chicken's diet.

2.0 Methodology

2.1 Experimental site

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, Oyo State. Ogbomoso is located on the 80101 north of the equator and 40101east of the Greenwich meridian. It is a derived Savannah region with an average annual rainfall of 1070mm and an average temperature of 26.1oC.

2.2 Test ingredient

Fresh cashew apples were sourced after the removal of the nut from local farms in Ogbomoso and its environs. The apples were rinsed under running water to remove contaminants and pressed mechanically to drain out the juice. The residue was then sun-dried to attain constant weight. The DCA was ground using a hammer mill to pass through a 2 mm sieve before incorporating it into the experimental diets. A sample of the DCA was collected for subsequent chemical analysis.

2.3 Experimental animals and management

Two hundred and ten (210) 1- day-old Ross chicks were used for the trial. Broiler chicks were weighed and randomly allotted into seven (7) groups with 30 birds each. The groups were further divided into three (3) replicates containing 10 birds each. Birds were housed in a deep litter open-sided house partitioned into cells. Wood shavings were used as litter materials and constant management of the litter was maintained through frequent aeration and litter changing. Electricity was the main source of heat while supplementary heat and lighting were provided using charcoal and rechargeable lamps respectively. Feed and water were supplied ad libitum.

2.3.1 Enzyme (POLYZYME ™)

The enzyme that was used in the study is a multi-enzyme cocktail for poultry (Polyzyme ™). It contains Xylanase 750-1050 U/g, Phytase 75-150 U/g, Cellulase 525-700 U/g, Beta-glucanase 375-500 U/g, Pectinase 200-300 U/g, Alpha-Amylase 2700-3400 U/g, Protease <1200 HUT/g. The multi-enzyme helps to improve the nutritional value of the feed by increasing the bioavailability and assimilation of nutrients present in the feed. The enzyme is in powdery form and was added to the diets at the level recommended by the manufacturer (500g – 2 kg per ton of feed).

2.4 Experimental diets

Feed ingredients for the formulation of the experimental diets were purchased at a local feed mill around Ogbomoso. The experimental diets were formulated to be iso-nitrogenous and iso-caloric to meet the nutritional requirement of broiler chicken (NRC, 1994). As shown in Tables 1 and 2 for the starter and finisher phases of the experiment. Diet 1 (control diet) is the basal diet containing maize and soya bean meal as the major sources of energy and protein, respectively. It contains 0% DCA and no enzyme supplementation. Diets 2, 3, and 4 contain 10, 20, and 30% DCA levels, respectively without enzyme supplementation. Diets 5, 6, and 7 also contain 10, 20, and 30% DCA levels, respectively with enzyme supplementation.

Table 1: Gross composition of the starter diets

Feed Ingredients (%)	Control (0%) DCA	T2 (10%) DCA	T3 (20%) DCA	T4 (30%) DCA	T5 (10%) DCA + Enzyme	T6 (20%) DCA + Enzyme	T7 (30%) DCA +Enzyme
Maize	57.00	51.30	45.60	39.90	51.30	45.60	39.90
Soy Bean Meal	29.00	29.00	29.00	29.00	29.00	29.00	29.00
Fish Meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
DCA*	0.00	5.70	11.40	17.10	5.70	11.40	17.10
Wheat Offal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Bone Meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Oyster Shell	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vit premix**	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Polyzyme***	-	-	-	-	+	+	+
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
<u>Calculated Composition (%)</u>							
Crude Protein %	22.31	22.48	22.64	22.81	22.48	22.64	22.81
ME (kcal/kg)	2910.8	2884.58	2858.35	2832.13	2884.58	2858.35	2832.13
Crude Fiber	4.34	5.02	5.7	6.38	5.02	5.70	6.38
Ether Extract	3.37	3.62	3.87	4.13	3.62	3.87	4.13
Methionine	0.59	0.58	0.57	0.56	0.58	0.57	0.56
Lysine	1.37	1.36	1.34	1.33	1.36	1.34	1.33
Phosphorous	0.51	0.50	0.50	0.49	0.50	0.50	0.49
Calcium	1.12	1.12	1.12	1.12	1.12	1.12	1.12

*DCA: Dried Cashew Apple

**Vitamin premix: Vit. A 30789 IU, Vit.D 36 IU, Vit.E 115 IU, Vit. K 77mg, Thiamine 39 mg, Pyridoxine 39 mg, Riboflavin 115 mg, calcium pantothenate 173 mg, Nicotinic acid 346 mg, VitB12 0.31 mg, Folic acid 19 mg, Manganese 3 g, Zinc 2 g, Iron 1 g, Copper 115 g, Iodine 38 mg, Cobalt 8 mg, Selenium 4 mg, Antioxidant 4 g, Chloride 8 g.

*** Polyzyme Composition: Xylanase 750-1050 U/g, Phytase 75-150 U/g, Cellulase 525-700 U/g, Beta-glucanase 375-500 U/g, Pectinase 200-300 U/g, Alpha-Amylase 2700-3400 U/g, Protease <1200 HUT/g.

Table 2: Gross composition of the finisher diets

Feed Ingredients (%)	Control (0%) DCA	T2 (10%) DCA	T3 (20%) DCA	T4 (30%) DCA	T5 (10%) DCA + Enzyme	T6 (20%) DCA + Enzyme	T7 (30%) DCA + Enzyme
Maize	57.00	51.30	45.60	39.90	51.30	45.60	39.90
Soy Bean Meal	22.00	22.00	22.00	22.00	22.00	22.00	22.00
Fish Meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
DCA*	0.00	5.70	11.40	17.10	5.70	11.40	17.10
Wheat Offal	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Bone Meal	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Oyster Shell	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
VitPremix**	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Polyzyme***	-	-	-	-	+	+	+
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Calculated Composition (%)							
Crude Protein (%)	20.40	20.56	20.73	20.89	20.56	20.73	20.89
ME (kcal/kg)	2837.61	2811.39	2785.16	2758.94	2811.39	2785.16	2758.94
CF	4.65	5.33	6.01	6.69	5.33	6.01	6.69
EE	3.54	3.79	4.05	4.3	3.79	4.05	4.30
Methionine	0.57	0.56	0.55	0.54	0.56	0.55	0.54
Lysine	1.23	1.21	1.20	1.18	1.21	1.20	1.18
Phosphorus	0.47	0.47	0.46	0.46	0.47	0.46	0.46
Calcium	1.13	1.13	1.13	1.13	1.13	1.13	1.13

*DCA: Dried Cashew Apple

** Vitamin premix: Vit. A 30789 IU, Vit.D 36 IU, Vit.E 115 IU, Vit. K 77 mg, Thiamine 39 mg, Pyridoxine 39 mg, Riboflavin 115 mg, calcium pantothenate 173 mg, Nicotinic acid 346 mg, VitB12 0.31 mg, Folic acid 19 mg, Manganese 3 g, Zinc 2 g, Iron 1 g, Copper 115 g, Iodine 38 mg, Cobalt 8 mg, Selenium 4 mg, Antioxidant 4 g, Chloride 8 g.

*** Polyzyme Composition: Xylanase 750-1050 U/g, Phytase 75-150 U/g, Cellulase 525-700 U/g, Beta-glucanase 375-500 U/g, Pectinase 200-300 U/g, Alpha-Amylase 2700-3400 U/g, Protease <1200 HUT/g.

2.5 Experimental design

The chick were weighed and randomly allotted to seven (7) treatment groups with three (3) replicates of ten (10) chicks each in a 2 x 4 factorial design.

2.6 Data collection

2.6.1 Growth performance

The following growth performance parameters were measured throughout the study.

Average Daily Feed Intake (ADFI): This was estimated using the formula below:

ADFI ={(Feed Intake)/(Number of birds)}/(Number of days)

Average Daily Gain (ADG): This was estimated using the formula below:

ADG = (Weight Gain)/(Number of Days)

Feed Conversion Efficiency (FCR): This was estimated using the formula below:

FCR= (Feed Intake)/(Weight Gain)

2.6.2 Carcass Characteristics

At the end of the fifth week, a total of 21 birds (1 bird per replicate) were selected at random and fasted for 12 hours to empty the crop content. The birds were then slaughtered; after draining the blood completely, each bird was eviscerated and weighed accordingly. Moreover, the de-feathered weight was taken after the removal of the feather; carcass weight was also taken after the removal of the head and the shank; the following primal cuts: breast, thigh, drumstick, and back were also weighed and expressed as a percentage of the live weight using the formula below:

Relative weight of primal cut=(Weight of cut)/Liveweight X 100

3.0 Results and Discussion

3.1 Results

3.1.1 Proximate Composition of Dried Cashew Apple (DCA)

The dry matter content of DCA is 87.82% and contains crude protein 21.01%, crude fiber 11.39%, ether extract 1.70%, nitrogen-free extract 36.34%, neutral detergent fiber 51.32%, acid detergent fiber 39.62%, acid detergent lignin 145.28%, hemicelluloses 11.70% and cellulose 25.34%

Table 3: Proximate Composition of Dried Cashew Apple

Parameters	Values
Dry Matter	87.82%
Crude Protein	21.01%
Crude Fibre	11.39%
Ether Extracts	1.70%
Ash	17.38%
NFE	36.34%
Metabolizable Energy*	2186.97 kcal/kg
NDF	51.32%
ADF	39.62%
ADL	14.28%
Hemicellulose	11.70%
Cellulose	25.34%

*Metabolizable Energy (ME) is calculated adopting the procedure of Pauzenga, (1985): ME (kcal/kg) = 37 X %Protein + 81 X %Fat + 35.5 X %Nitrogen Free Extract. NFE: Nitrogen Free Extract, NDF: Neutral Detergent Fibre, ADF: Acid Detergent Fibre, ADL: Acid Detergent Lignin

3.1.2 Growth performance

The summary of growth performance characteristics of broiler chickens fed diets containing graded levels of DCA as a replacement for maize are shown in Table 4. All parameters (final weight, weight gain, and ADG) were significantly influenced by the dietary treatments. Birds fed diets T2 (10% DCA no enzyme) and T5 (10% DCA with enzyme) had the highest values for the parameters tested. These values were statistically similar to those obtained from birds fed the control diet (T1 0% DCA with enzyme), they were higher. Birds fed diets T4 (30% DCA no enzyme), T6 (20% with enzyme and T7 (30%With Enzyme) have the lowest values while birds fed diet T3 (20% DCA no enzyme) showed the same response as birds fed the control diet (T10% DCA). Moreover, ADFI and FCR were also significantly ($P<0.05$) affected by the dietary treatment as birds fed with the control diet (T1 0%DCA) had the least values for ADFI and FCR while there was a quadratic increase in values obtained across other dietary treatments as the inclusion level of DCA increases despite enzyme supplementation. The interactive effect of feeding diets containing varying levels of DCA and enzyme supplementation on ADG, ADFI and FCR of broiler chickens was significant ($P < 0.05$) (Table 5). There were also significant ($P<0.05$) differences in all parameters measured except for initial weight as the inclusion level of DCA increases. However, enzyme supplementation had no noticeable effect on the growth performance of broiler chickens fed diets containing graded levels of DCA as a replacement for maize supplemented with or without enzyme.

Table 4: Growth performance of broiler chicken fed diets containing graded levels of DCA

	Diets*							
Parameters	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**SEM**
Initial Weight (g/bird)	45.93	46.03	45.83	46.2	45.93	46.13	46.03	0.18
Final Weight (g/bird)	1335.74ab	1393.47a	1330.96ab	1245.39b	1390.98a	1282.05b	1251.78b	10.89
Weight Gain (g/bird)	1289.81ab	1347.44a	1285.13ab	1199.19b	1345.05a	1235.92b	1205.74b	10.89
ADFI (g/bird/day)	72.97d	88.57bc	82.88c	100.06a	88.71bc	81.33c	95.85ab	0.92
ADG (g/bird/day)	36.85ab	38.50a	36.72ab	34.26b	38.43a	35.31b	34.44b	0.31
FCR	2.00c	2.30b	2.26b	2.92a	2.31b	2.31b	2.80a	0.03

a b c Means within rows for different groups with different superscripts differ (P < 0.05)

*Diets

T1: (0% DCA without enzyme), T2: (10% DCA without enzyme), T3: (20% DCA without enzyme), T4: (30% DCA without enzyme), T5: (10% DCA with enzyme), T6: (20% DCA with enzyme), T7: (30% DCA with enzyme)

ADFI: Average Daily Feed Intake, ADG: Average Daily Gain, FCR: Feed Conversion Ratio, SEM: Standard Error Mean

Table 5: Interaction Effect of Varying Levels of DCA and Enzyme Supplementation on Growth Performance of Broiler Chicken

Parameters	**Enzyme**	**Control**	**10%**	**20%**	**30%**	**SEM**
Initial Weight (g/bird)	No Enzyme	45.93	46.03	45.83	46.20	0.33
	With Enzyme	45.93	45.13	46.13	46.03	0.33
	SEM	0.47	0.47	0.47	0.47	
Final Weight (g/bird)	No Enzyme	1335.74b	1393.48a	1330.96b	1245.39c	20.37
	With Enzyme	1335.74b	1390.98a	1282.05c	1251.78c	20.37
	SEM	28.81	28.81	28.81	28.81	
Weight Gain (g/bird)	No Enzyme	1289.81b	1347.44a	1285.13b	1199.19c	20.38
	With Enzyme	1289.81b	1345.05a	1235.92c	1205.74c	20.38
	SEM	28.82	28.82	28.82	28.82	
ADG (g/bird/day	No Enzyme	36.85b	38.50a	36.72b	34.26c	0.58
	With Enzyme	36.85b	38.43a	35.31c	34.45c	0.58
	SEM	0.82	0.82	0.82	0.82	
ADFI (g/bird/day)	No Enzyme	72.97d	88.57b	82.88c	100.06a	1.72
	With Enzyme	72.97d	88.71b	81.33c	95.85a	1.72
	SEM	2.44	2.44	2.44	2.44	
FCR	No Enzyme	2.00c	2.30b	2.26b	2.92a	0.06
	With Enzyme	2.00c	2.31b	2.31b	2.80a	0.06
	SEM	0.08	0.08	0.08	0.08	

a b c Means within rows for different groups with different superscripts differ (P < 0.05)

ADFI: Average Daily Feed Intake, ADG: Average Daily Gain, FCR: Feed Conversion Ratio,

SEM: Standard Error Mean

3.1.6 Carcass characteristics

There were significant (P<0.05) differences in the values of all parameters considered except for bled weight, thigh, head, and shank (Table 6). Birds fed with diet T2 recorded the highest value for live weight, while the least value was recorded for birds fed with diet T7, and significantly different values were recorded in birds fed the control diet (T1), T3, T4, T5 and T6. The highest de-feathered weight was recorded in birds fed diet T5 with 999g, and the lowest de-feathered weight of 886.67g was recorded in birds on diet T7 while birds on the control diet T1, T2, T3, T4, and T6 had 934.67g, 993.33g, 967.33g, 948.33g, and 939.00g respectively which were significantly different from values observed for birds on diets T5 and T7. Eviscerated weight and Carcass weight followed the same trend as De-feathered weight.

Birds on diet T3 had the highest (P<0.05) value of 303.67g for breast yield, while the lowest value of 211.67g was recorded for birds on diet T6; significantly different values were also observed from birds on the control diet T1, diets T2, T4, T5 and T7. Moreover, birds on diets T2 and T5 had the highest drumstick values of 136.00g and 137.67g respectively, and the lowest values were recorded in birds on diets T3 and T6 while values observed in birds on the control diet T1, diet T4 and T7 were statistically similar and significantly different from those obtained from birds on other dietary treatments. A significant difference was observed in the value for wing yield as birds on the control diet T1 had a significantly lower value of 86.67g compared to those observed from other dietary treatments.

Table 6: Carcass Yield of Broiler Chickens Fed Diet Containing Graded Levels of DCA as Replacement for Maize Supplemented with or Without Enzyme

Parameters (g)	Diets*							SEM
	T1	T2	T3	T4	T5	T6	T7	
Live Weight	1265.67ab	1360.00a	1279.33ab	1257.67ab	1300.67ab	1246.00ab	1179.33b	16.11
Bled Weight	1233.67	1270.67	1246.00	1219.33	1267.00	1217.33	1140.33	16.02
De-feathered Weight	934.67ab	993.33ab	967.33ab	948.33ab	999.00a	939.00ab	886.67b	12.96
Eviscerated Weight	967.33ab	1047.00a	1019.67ab	983.00ab	1043.67a	978.00ab	913.67b	12.91
Carcass Weight	839.00ab	900.67a	877.33ab	849.00ab	898.67a	838.33ab	782.33b	11.36
Breast	263.00ab	275.67ab	303.67a	266.67ab	255.00abc	211.67c	238.00bc	6.10
Thigh	119.33	131.67	128.67	119.33	134.33	135.33	123.00	2.21
Drumstick	126.33ab	136.00a	116.00b	122.00ab	137.67a	117.00b	125.33ab	2.21
Back	188.00bc	206.33ab	173.67c	167.67c	215.33a	184.67bc	178.67c	3.32
Wing	86.67b	102.00a	98.00a	102.33a	101.00a	100.67a	96.33ab	1.28
Head	35.67	39.67	35.67	37.67	36.33	37.33	34.67	0.59
Shank	51.67	51.00	48.33	52.67	53.00	53.67	53.67	0.87

a b c Means within rows for different groups with different superscripts differ (P < 0.05)

*Diets: T1: (0% DCA without enzyme), T2: (10% DCA without enzyme), T3: (20% DCA without enzyme), T4: (30% DCA without enzyme), T5: (10% DCA with enzyme), T6: (20% DCA with enzyme)

T7: (30% DCA with enzyme), b: Standard Error Mean

3.1.7 Organ weight

Organs weighed included liver, heart, lungs, kidney, GIT, abdominal fat, bursa, pancreas, gizzard, and spleen. Significant (P<0.05) differences were observed in all parameters measured except for the heart (Table 7). The liver weight of birds fed with diet T4 was significantly (P<0.05) higher than all other dietary treatments while the lowest liver weight was recorded in birds fed the control diet T1. Birds on diets T2, T3, T5, T6 and T7, all had liver weights that were statistically similar and significantly (P<0.05) different from what was observed in birds fed the control diet T1. Birds on diets T3 and T6 had the highest values of 0.58% and 0.51% respectively for lungs, while the lowest value of 0.48% was observed in birds on diet T7 which was significantly different from the value (0.50%) obtained from birds on the control diet T1.

Birds fed diet T3 had the highest value of 0.60% for kidneys, and the least values of 0.32, 0.29, and 0.34 were recorded in birds fed the control diet T1, diets T2, and T4. Additionally, the highest GIT value of 10.06% was recorded in birds on diet T6, while birds on diet T2 had the least GIT weight of 7.16% which was significantly (P>0.05) different from the GIT weight (8.48%) of birds on the control diet T1. Moreover, a significant (P<0.05) difference was also observed in the percentage of abdominal fat across the dietary treatments. Birds on diet T2 had the highest value of 1.00%, while the least abdominal fat level of 0.31% was observed in birds fed diet T5; both values were significantly different from the value of 0.36% obtained from birds fed the control diet T1.

Bursa weight was also significantly influenced by the dietary treatments as birds on diet T3 and T5 had the highest values of 0.16% and 0.15% respectively, the least value of 0.08% was observed in birds on diet T4 while birds on the control diet T1 had a significantly different value of 0.13%. Birds fed diet T6 had the highest value of 0.38% for the pancreas, and the least value of 0.26% was recorded in birds fed diet T3, while a significantly (P<0.05) different value of 0.32% was recorded for birds fed the control diet T1.

Whole gizzard and empty gizzard followed the same trend as a statistically similar response was observed across the dietary treatments except for birds fed diet T7 which has a significantly (P<0.05) higher values of 4.49% and 3.09% for whole gizzard and empty gizzard, respectively.

Table 7: Organ Weight of Broiler Chickens Fed Diets Containing Graded Levels of DCA Supplemented With and Without Enzyme.

Parameters (% Live Weight)	Diets*							SEM
	T1	T2	T3	T4	T5	T6	T7	
Liver	1.98c	2.42b	2.40b	2.99a	2.26bc	2.44b	2.30bc	0.04
Heart	0.48	0.42	0.47	0.48	0.41	0.48	0.47	0.01
Lungs	0.50ab	0.56ab	0.58a	0.50ab	0.51ab	0.59a	0.48b	0.01
Kidney	0.32c	0.29c	0.60a	0.34c	0.41bc	0.51ab	0.54ab	0.02
GIT**	8.48ab	7.16b	8.02ab	9.01ab	8.15ab	10.06a	9.03ab	0.25
Abdominal Fat	0.36cd	1.00a	0.67bc	0.62bcd	0.31d	0.35cd	0.81ab	0.04
Bursa	0.13ab	0.10bc	0.16a	0.08c	0.15a	0.11bc	0.09bc	0.01
Pancreas	0.32ab	0.27ab	0.26b	0.32ab	0.36ab	0.38a	0.34ab	0.01
Whole Gizzard	3.20c	3.22c	3.89b	3.50bc	3.68bc	3.61bc	4.49a	0.07
Empty Gizzard	2.51b	2.36b	2.68b	2.54b	2.51b	2.57b	3.09a	0.04
Spleen	0.14b	0.12b	0.11b	0.32a	0.10b	0.13b	0.14b	0.01

[a b c] Means within rows for different groups with different superscripts differ ($P < 0.05$)

*Diets: T1: (0% DCA without enzyme), T2: (10% DCA without enzyme), T3: (20% DCA without enzyme), T4: (30% DCA without enzyme), T5:(10% DCA with enzyme), T6: (20% DCA with enzyme) T7: (30% DCA with enzyme) *GIT: Gastro-intestinal tract SEM: Standard Error Mean

3.2 Discussion

Dried cashew apple (DCA) proximate analysis and fiber characterization shows DCA to have a better feed value and these values were slightly different from those reported by Fanimo et al. (2003) who documented dry cashew pulp waste (a variant of DCA) contained 18% CP, 8.4% CF, 2.4% fat, and 5.4% ash. Results obtained for the proximate analysis were similar to those reported by Castillo and Gerpacio, (2005). They reported that DCA contained 85.53% DM, 8.62% CP, 5.86 CF, 5.86% fat, 2.71% ash, and 64% NFE. However, our results were slightly different from those reported by Fanimo et al. (2003) who documented that dry cashew pulp waste contained 18% CP, 8.4% CF, 2.4% fat, and 5.4% ash. The observed differences might be due to the processing methods employed in preparing DCA.

Birds fed diets containing 10% DCA supplemented with or without enzyme diets T2 and T5 had the highest final weight, weight gain, and average daily gain (ADG), while the least values were recorded in birds fed diets T4 and T7. This is consistent with the findings of Yisa and Longe, (2020) who reported that inclusion of DCA up to 10% in broiler chickens results in no loss of performance as measured by growth, however, this contradicts the finding of Swain et al. (2007), that dietary inclusion of cashew apple waste as a replacement for maize (5-20%) significantly depress growth performance as measured by body weight gain. The performance of birds fed the diet containing 20% DCA is comparable to that of the birds fed the control diet (T1). This could be attributed to the better proximate composition of DCA in this study showing a better feeding value than what was reported by previous studies as discussed above. The reduced performance observed in birds fed diets T4 and T7 could be because DCA as a high dietary fiber feed ingredient, reduces broiler chicken's performance as its concentration in the diets increases (Lumpkins et al, 2004). Furthermore, Rochell (2012), associate increased rate of feed passage, reduced meal retention time, and poor nutrient digestion to a higher concentration of fiber in broiler chickens diets which ultimately affect performance adversely. However, supplementation with enzyme makes broiler chickens tolerate dietary inclusion of DCA up to 20 % as birds fed diet T6 performed comparably to birds fed the control diet. T1. This could be a result of increased nutrient availability and digestibility attributed to supplementing poultry feed with exogenous carbohydrase (Emiola et al., 2009).

Dietary inclusion of DCA in broiler chicken's diet significantly affects the average daily feed intake (ADFI), and feed conversion ratio (FCR) as birds fed the control diet T1 (72.97g; 2.0) had the lowest value while the highest values were observed in birds fed diets T4 (100.06g; 2.92), and T7 (95.85g; 2.80). This finding supports Yisa and Longe, (2020) who reported an increase in feed intake and FCR in response to dietary inclusion of DCA as a replacement for maize in broiler chicken's ration. This may be attributed to the fact that DCA is a fiber-rich feed ingredient that tends to reduce the energy density of the feed and poultry birds often eat to satisfy their energy requirement (Unigwe 2011; Hossain et al, 2012) making the birds consume more feed as the inclusion level of DCA increase to 30%.

Carcass yield is a vital index in measuring the performance of broiler chickens because they are specifically raised for meat production. The carcass yield analysis shows that birds fed the diets containing 10% DCA supplemented with and without enzyme (diets T2 and T5) had a superior performance over other dietary treatments with respect to live-weight, de-feathered weight, eviscerated weight and carcass weight. Birds fed diets containing 20% DCA have carcass yield comparable to those fed the control diet. This response could be due to the improved feeding value of DCA observed in this study. Moreover, the fairly high energy observed in DCA coupled with the fact that DCA is not the primary source of protein in the experimental diet indicates that the protein in the feed is not compromised by the inclusion of DCA up to 20% as the experimental birds received adequate protein from the diet for muscle development and accretion.

A quadratic response was observed in the analysis of the organ weight relative to the live weight of the experimental birds used in this study suggesting that the difference observed is not due to the dietary inclusion of DCA in broiler chicken's diet. Moreover, the weights of the major organs taken in this study were similar to those reported by past studies (Swain et al, 2007; Kokoszyńskiet al, 2016). This suggests that DCA is free from harmful toxic compounds.

4. Conclusion and Recommendation

4.1 Conclusion

Dietary inclusion of DCA in broiler chicken's diet as a replacement for maize up to 20% did not trigger any adverse effect on weight gain and average daily gain. However, feed intake, and feed conversion ratio increase with increasing level of DCA. Also, including DCA up to 20% had no adverse effect on the carcass conformation of broiler chickens as birds fed diets containing 20% DCA had carcass yield comparable to those obtained from birds fed the control diet, T1.

4.2 Recommendation

It is therefore recommended that DCA up to 20% may be incorporated into broiler chicken's diet as a replacement for maize for optimum growth performance and economic benefit.

Acknowledgement

This research was supported with funding from STARLINK GLOBAL & IDEAL LIMITED, Starlink House, 106/108, Apapa- Oshodi Expressway, Aswani, Isolo Industrial Estate, Lagos, Nigeria.

References

Alahira, J. (2013). Cashew Production. Retrieved from https://www.agriculturenigeria.com /manuals /production /crop-production/cash-crops/cashew-production/

Ani, A. O., Omeje, O. D., and Ugwuowo L. C. (2012). Effects of raw Bambara nut (Voandzeiasubterranea l) waste and enzyme complex on growth performance an apparent nutrient retention in broiler chickens. African Journal of Biotechnology Vol.11(56), pp. 11991-11997.

Antony A P, Kunhiraman S and Abdulhameed S (2020). Bioprocessing with cashew apple and its by-products. In Book: Valorization of Agro-Industrial Residues – Volume II: Non-Biological Approaches, Pp.83-106.

Bedford, M. (2000).Exogenous Enzymes in Monogastric Nutrition – Their Current Value and Future Benefits.Animal Feed Science and Technology.86. 1-13. 10.1016/S0377-(00)00155-3.

Castillo F. and Gerpacio L. (2005). Nutrient composition of Philippine Feedstuff, University of the Philippines, Printing Press, Los Banos Laguna (2005)

Dieumou F. E., Adegbola T. A. and Doma U. D. (2013). Growth performance, carcass characteristics, and economics of production of broilers fed diets with two sources of protein and two levels of wheat offal. Journal of Cereals and Oilseeds.Vol. 4(4), Pp. 42-47, July 2013.

Durunna, C. S., Udedibie, A. B. I. and Uchegbu, M. C. (2005). Effect of dietary inclusion of Anthoatamacrophyla meal on the performance of starter chicks. Nigeria Journal of Animal Science. 32, 268 - 273.

Ekanem N., Essien E., and Thompson L. (2016). Carcass Characteristics and Internal Organs of Broilers Fed Varying Levels of Full Fat Palm Kernel Meal. Journal of Biology, Agriculture, and Healthcare.Vol.6, No.18.

Emiola A, Opapeju F, Slominski B, Nyachoti M. (2009). Growth performance and nutrient digestibility in pigs fed wheat distillers dried grains with solubles-based diets supplemented with a multicarbohydrase enzyme. Journal of Animal Science 87:2315-2322.

Fanimo, A. O., Oduguwa, O. O., Alade, A. A., Ogunnaike, T. O., and Adesehinwa, A. K. (2003). Growth performance, nutrient digestibility, and carcass characteristic of growing rabbits fed cashew apple waste. Livestock Research for Rural Development. Volume 15, Article #58. Retrieved January 5, 2022, from http://www.lrrd.org/lrrd15/8/fani158.htm

Hossain, M. A., Islam, A. F., and Iji, P. A. (2012). Energy Utilization and Performance of Broiler Chickens Raised on Diets with Vegetable Protein of Conventional feeds. Asian Journal of Poultry Science. 6(4): 117-128.

Kokoszyński D, Bernacki Z, Saleh M, Stęczny K, Binkowska M. (2016). Body Conformation and Internal Organs Characteristics of Different Commercial Broiler Lines. Brazilian Journal of Poultry Science ISSN 1516-635X

Lumpkins, B. S., Batal, A. B., and Dale, N. M., (2004). Evaluation of distillers dried grains with solubles as a feed ingredient for broilers. Poultry Science. 83, 1891-1896.

NRC (1994). Nutrient Requirement of Poultry. 9th Revised Edition. National Research Council. Washington.

Pauzenga. (1985). Feeding parent stock. Zoo Technical International. Pp 22-23.

Rochell, J.S., Applegate, J. T., Kim J. E., and Dozier III, A. W., (2012). Effect of diet type and ingredient composition on the rate of passage and apparent ileal amino acid digestibility in broiler chicks. Poultry Science. 91, 1647-1653.

Soltan, M. A. (2009). Growth performance, Immune response and, carcass traits of broiler chicks fed on graded levels of palm kernel cake without or with enzyme supplementation. Livestock Research for Rural Development, 21(3): 1-11.

Swain B K, Sundaram R N S and Barbuddhe S B (2007). Effect of Feeding Cashew Apple Waste Replacing Maize On the Performance of Broilers. Indian Journal of Poultry Science. 42(2): 208-210.

Tai, V. A., Tuan, B. Q., Van, T. T., and Nguyen Xuan Trach (2020). Use of cashew apple fruit silage in the cattle fattening diet. Livestock Research for Rural Development. 35. Article #72

Tuan, B.Q. (2007). Investigation on the utilization of agricultural and industrial by-products as feedstuffs. Final project report. Ministry of Agriculture and Rural Development, Hanoi, Vietnam.

Unigwe, C. R. (2011). The impact of replacement of maize with graded cassava root meal on the haematology and growth performance of starter broiler. Continental Journal of Animal and Veterinary Research, 3: 1-6.

Yisa, I. K., and Longe, O. G. (2020). Growth response and carcass characteristics of broiler chickens fed dried cashew (Anacardium occidentale L.) apple pulp in replacement for maize. Livestock Research for Rural Development 32 (5)

PROJECTION OF THE IMPACT OF CLIMATE CHANGE ON THE PRODUCTIVITY OF *ANACARDIUM OCCIDENTALE L.* IN BENIN

AYENA I. K. Jacques[1], GOUWAKINNOU N. Gérard1 & HOUEHANOU D. Thierry[1]

1. Laboratory of Ecology, Botany and Plant Biology (LEB), Parakou, Benin, idohouayena@gmail.com ; gougerano@gmail.com & houehanout@gmail.com

Abstract

Climate change is an environmental issue that deserves special attention in agricultural production planning, diversification of agricultural production and conservation. Anacardium occidentale appears today as a strategic crop with promising prospects for development and guaranteed income for sustainable farm diversification. It is against this background that this work carried out in Benin aims to identify optimal areas likely to host plantations for greater resilience to climate change. To identify these areas, the Maximum Entropy Principle (MaxEnt) was used in conjunction with the Geographic Information System (GIS). The HadGEM3-GC31-LL climate model from the Coupled Model Intercomparison Project Phase 6 (CMIP6) dataset was used for climate projections under three Intergovernmental Panel on Climate Change (IPCC) scenarios: SSP1-2.6, SSP2-4.5 and SSP5-8.5 to 2061-2080. Bioclimatic variables associated with the occurrence points were used to run the model. The models indicate that about 13.55% of the habitats are currently highly favourable for Western Anacardium cultivation with a dominance of the Sudano-Guinean zones. Future projections predict very significant variations in these habitats. By 2061-2080, under the SSP1-2.6, SSP2-4.5, and SSP5-8.5 scenarios, habitats will increase by 43.86%, 76.76%, and 86.13% respectively. All three scenarios indicate that the national land area will be almost highly favourable by 2070 (2061-2080). The results show that the habitats favourable for western Anacardium cultivation are currently negatively influenced by climatic hazards, which may become positive by 2070. As areas become drier, habitats will become increasingly favourable, so it will be important to consider Anacardium occidentale in policies to reduce drought areas.

Keywords: *Anacardium occidentale*, climate change, Benin

1.0 Introduction

Originally from Brazil (Sivagurunathan et al., 2010) and introduced in West and East Africa in the 18th centuries by the Portuguese (Sauer, 1993), Anacardium occidentale L., Anacardiaceae appears today as a strategic crop with very promising prospects for development and guaranteed income for sustainable farm diversification. Indeed, its production helps to solve many development problems and is an economic source of income for producing countries. With more than 120,000 tons exported since 2011 (Ricau, 2013; Balogoun et al. , 2014), cashew nuts contribute 24.87% of agricultural export income for Benin, and help improve the income of many producers. The species has become an interesting alternative (Aïvodji & Anasside, 2009) for exports after cotton (Yabi et al., 2013; Balogoun et al., 2014). Benin provides nearly 3.5% of the world's raw nut production economically. This production prowess has brought the country to the sixth place in the world with about 3.8% of the volume of nuts produced and third place among West African countries after Nigeria and Côte d'Ivoire (FAO, 2014). Thus, it ranks among the world's top ten cashew nut producers.

Despite the importance of cashew, several abiotic and biotic constraints compromise the production of the tree. Thus, cashew production is confronted with climatic variability despite the multiple opportunities it offers both nationally and internationally (Adegbola et al., 2005). According to cashew producers in Central and Northern Benin, climatic factors affect cashew productivity (Djènontin, 2013; Tchétangni, Assogbadjo & Houéhanou, 2016). This climatic variability engenders the reduction of its many benefits through the decline in production. According to Yabi, (2008), problems of flower and fruit drop remain a major concern of cashew farmers and would be due to the agro climatic stress index and bi-monthly rainfall. This phenomenon of weather and seasonal variations has become a source of greater concern of all (Jayathilaka, et al., 2012). These unfavourable climatic conditions are the difficulties generally articulated by cashew farmers at various times during discussions on the sector and require further investigations for better control of the phenomenon (Tandjiekpon, et al., 2010).

2. Methodology

This work was carried out in Benin with particular emphasis on the three climatic zones. These are the Sudanian zone, the Sudano-Guinean zone and the Guinean-Congolian zone (Figure 1).

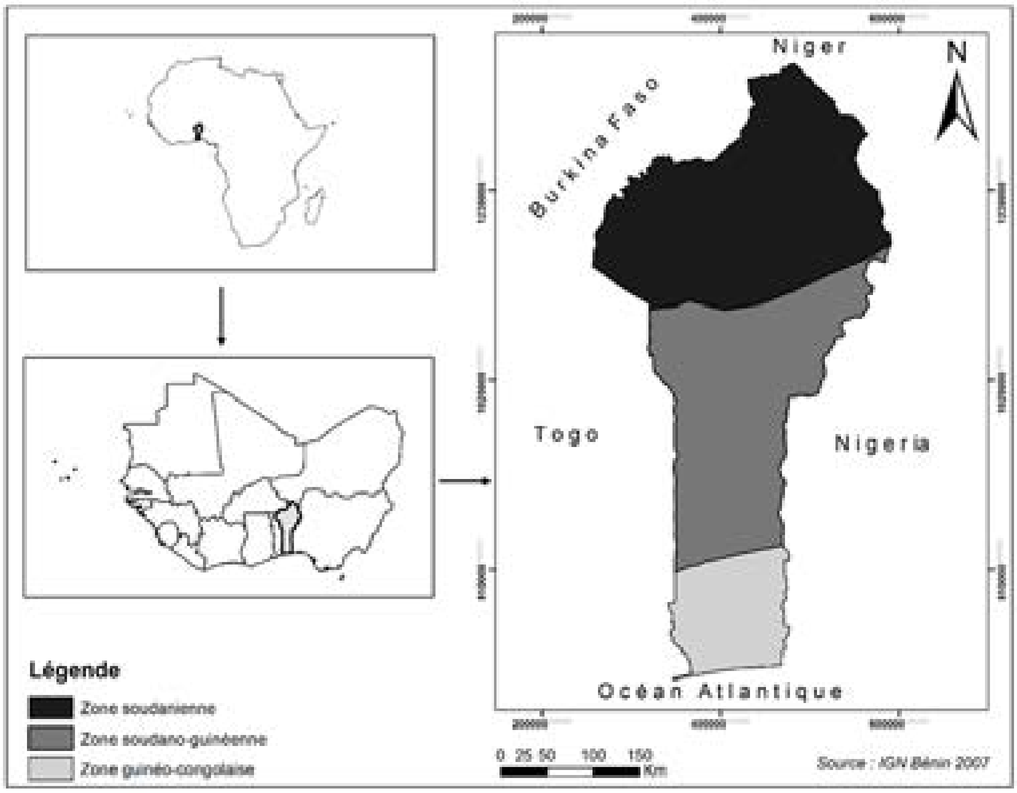


Figure 1: Study environment

Two types of data were required for the loss of suitable habitats for *Western Anarcadium*: occurrence points and bioclimatic variables. In addition to the occurrence points obtained from the fieldwork, we uploaded Africa-wide occurrence points to the Global Biodiversity Information Facility (GBIF) website (www.gbif.org). Based on the distribution of the occurrence points obtained, a mask was defined to run the models. This mask includes Benin (study area), Nigeria, Togo, Ghana and Ivory Coast (Figure 2). Being in a climate projection, we cannot do without bioclimatic variables. Thus, we downloaded 19 bioclimatic variables of 30s resolution from the Worldclim website (https://www.worldclim.org/data/index.html). These variables associated with the points of occurrence allowed us to evaluate the habitats favourable to the cultivation of *Western Anarcadium*.

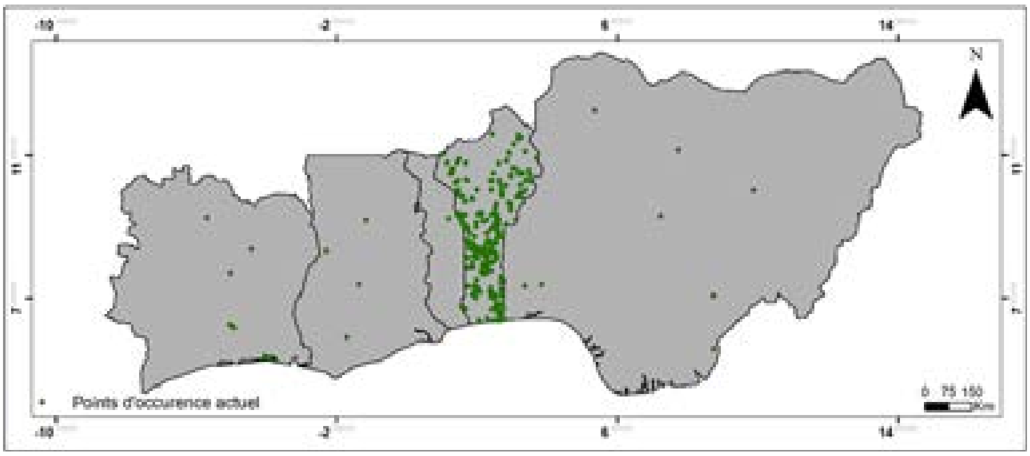


Figure 2: Distribution of the presence of *Anacardium occidentale*

The HadGEM3-GC31-LL climate model from the Coupled Model Intercomparison Project Phase 6 (CMIP6) dataset was used for climate projections under three Intergovernmental Panel on Climate Change (IPCC) scenarios: SSP1-2.6 (Sustainable Development Scenario), SSP2-4.5 (Intermediate Scenario) and SSP5-8.5 (Fossil fuel-based development scenario) by 2061 - 2080. Indeed, the SSPs are based on the details of socio-economic development exploring plausible developments in the world in the absence of additional policies and measures to limit global warming (Riahi et al, 2017).

Our mask-scale bioclimatic variables in ascii format were input data into the MaxEnt programme with Cross-validation as the partitioning method; 10 replicates; 10,000 backgrounds, 500 iterations and the Cloglog link function which is the default for running the models. These were calibrated with 80% of the pre-processed data and validated with the remaining 20%. The Area Under the Curve (AUC) statistic of Phillips, Anderson & Schapire (2005) allowed us to evaluate the models. A model is considered excellent when the AUC value obtained is greater than or equal to 0.90. Favourable habitat classes are defined using the ''10 percentile Training presence Cloglog threshold'' and then mapped in ArcGis 10.7 mapping software.

3. Results and discussion

As the distribution of a species is not equally influenced by climate components, the contribution of each variable used in the distribution model of Anacardium occidentale was evaluated using the Jackknife test (Figure 3). The three most predictive variables were isothermality (Bio 3), temperature seasonality (Bio 4) and rainfall in the driest quarter (Bio 17).

Figure 3: Jackknife test Legend: On the ordinate we have the environmental variables that contributed to the calibration of the model. The band in front of each variable gives information on the performance of the model: the blue band shows the performance of the model when it is run with the variable alone, the green band shows the performance of the model when it is run without the variable and the red band shows the performance of the model when it is run with all the variables

Our model proved to be efficient in the loss of favourable habitats for the cultivation of Anacardium occidentale because the AUC value generated is 0.94. Regarding the spatio-temporal dynamics of current and future favourable habitats, about 13.55% of the habitats are currently very favourable to the cultivation of Anacardium occidentale (Figure 5, Table 1), i.e., 1.05% in the Sudanian zone, 11.54% in the Sudano-Guinean zone and 0.97% in the Guinean-Congolian zone. We clearly see a clear domination of the Sudano-Guinean zone.

Furthermore, the climate projections reveal an increase in very favourable habitats at the expense of the loss of unfavourable and moderately favourable habitats by 2061-2080, i.e., on average by 2070. Thus, we have an increase of 43.86%, 76.76% and 86.13% in very favourable habitats under the SSP1-2.6, SSP4-4.5 and SSP5-8.5 scenarios respectively, with the Guineo-Congolian climate zone dominating (Figure 5, Table 1).

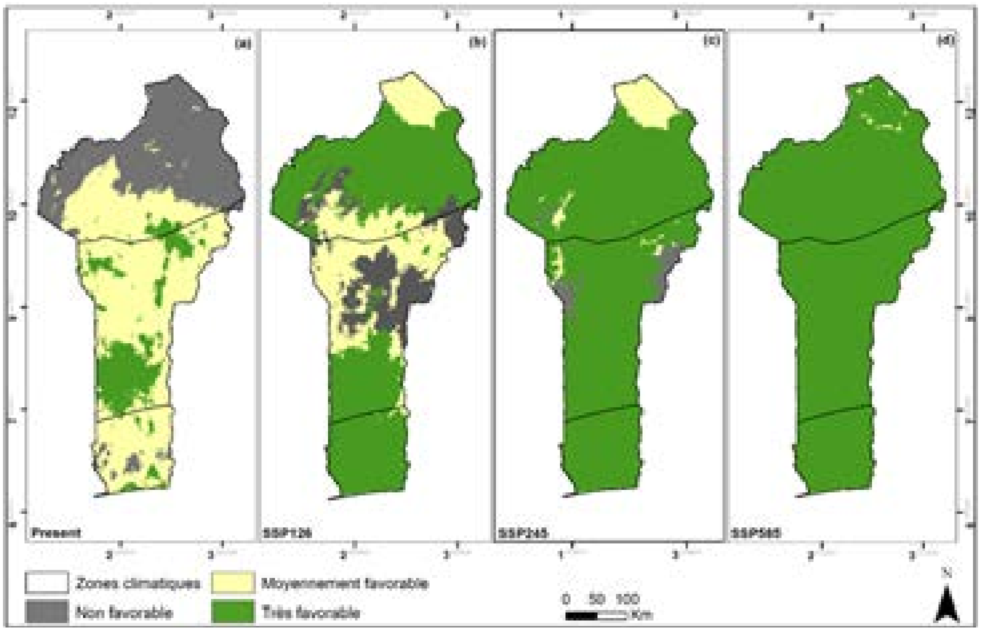


Figure 4: Spatial and temporal dynamics of habitats favourable to the cultivation of Anacardium occidentale

Table 1: Spatial and temporal dynamics of favourable habitats in area

Legend: Habitat Gain (+) and Habitat Loss (-)

3.2 Discussion and conclusion

Predictive models are frequently used by specialists in natural resource management and the impact of climate on species distribution (Beaumont et al. , 2005; Thuiller et al., 2005). They are of multiple order and make it possible to observe the distribution areas of a species statistically by taking into account ecological and climatic factors (Piedallu, 2009). This gives species' ecological niche modelling the status of a very powerful tool for mapping and assessing the impact of current and future climate change on species (Van Zonneveld et al., 2009). However, it is important to raise some uncertainties being in a simulation study. Aware that climate envelopes are subject to interpolation over several years, they nevertheless offer very important relevant results in natural resource management. With the finer resolution of our bioclimatic variables and a non-significant level of spatial error in the points of occurrence, the MaxEnt programme is very reliable in dealing with bias or error.

The 19 starting variables were reduced to 10 after performing the Jackknife test. However, we did not have to perform the correlation analysis as recommended by Warren, Richard & Turelli, (2010); Elith et al., (2011). Indeed, recent work by Feng et al., (2019) reveal that MaxEnt is robust enough to handle the contribution of redundant variables.

The results of our climatic projections stipulate that the habitats favourable to the cultivation of western Anacardium in Benin will be unstable in the future. Indeed, all scenarios predict a significant increase in very favourable habitats at the expense of unfavourable and moderately favourable habitats. This variation is close to the work of Djènontin, (2013) and Tchétangni, Assogbadjo & Houéhanou, (2016) on farmers' perception of the effects of climate change on cashew nut production. Currently, the very

		Not in favour		Moderately favourable		Very favourable		
Climatic zones	**Scenarios**	Area (Km^2)	Trend (%)	Area (Km^2)	Trend (%)	Area (Km^2)	Trend (%)	**Total (Km^2)**
Sudanian area	**Present**	36568.38	-	16657.26	-	1201.85	-	54427.50
	SSP126	4153.58	-88.64	12943.15	-22.30	37330.77	+3006.11	
	SSP245	395.54	-98.92	6129.59	-63.20	47902.37	+3885.72	
	SSP585	0	-100	372.77	-97.76	54054.73	+4397.63	
Sudano-Guinean area	**Present**	390.81	-	31552.68	-	13252.11	-	45195.60
	SSP126	13833.79	+3439.77	17762.55	-43.71	13599.26	+2.62	
	SSP245	3750.76	+859.74	856.28	-97.29	40588.56	+206.28	
	SSP585	0	-100	0	-100	45195.60	+241.04	
Guinean-Congolian zone	**Present**	1506.88		12626.22		1113.30		15246.4
	SSP126	0	-100	230.93	-98.17	15015.47	+1248.74	
	SSP245	0	-100	0	-100	15246.40	+1269.48	
	SSP585	0	-100	0	-100	15246.40	+1269.48	

favourable habitats are concentrated in the Sudano-Guinean zone; this would be due to the climatic requirement of the species which is for annual rainfall between 800 to 1800 mm and distributed consecutively over 5 to 7 months, with a dry season of 5 to 6 months favouring a good conservation of seeds. Sensitive to the cold with regard to significant temperatures, cashew tolerates 12 to 32°C and altitudes up to 1000 mm in privileged situation (Amandou Sanni, 2016).

Future climate projections indicate a very significant increase in highly favourable habitats, especially under the SSP2-45 and SSP5-85 scenarios, where a large area of highly favourable habitats for western Anacardium cultivation is observed in all three climate zones. These results will be due to the drying of the areas by 2061-2080 predicted by the climate models. However, in a world where our priority is to reduce drought, what should be done to adapt our policy to the distribution of Anacardium occidentale which is an economic potential?

In sum, the distribution of western Anacardium is influenced by climate change, but by 2070 almost the entire territory would be favourable for the cultivation of the species because of the increase in dry areas. This poses a problem as we struggle to reduce drought. The distribution of the species will have to be taken into account in the policies for the reduction of drought areas.

Acknowledgement

The authors thank Prof. Armand K. NATTA, Dr. Gérard N. GOUWAKINNOU and Dr. HOUEHANOU D. Thierry respectively Director of the Laboratory of Ecology, Botany and Plant Biology (LEB), Head and Deputy Head of the Biodiversity Conservation at the Interface People, Land Use and Climate Changes (BIPLaC) Research Unit for their financial and technical support.

References bibliography

Adegbola Y. P., Laurent Aloukoi L. and Sossou H. C., 2005. Report of the analysis of the competitiveness of the cashew nut sector in Benin. PAPA/INRAB, 35 p.

Adjahossou, S. G. C., Gouwakinnou, G.N., Houéhanou, D.T., Sodé, A.I., Yaoitcha, A.S., Houinato, M.R.B. & Sinsin, B. (2016). "Effectiveness of protected areas in the conservation of priority favourable habitats of valuable woody species in Benin". Tropical Timber and Forestry 2 (328): 10.

Aïvodji J. Anasside A., 2009. Elaboration of price stabilization and support rules for the cashew nut sector, 78p.

Amandou S. , A. , 2016. Perception of climatic factors on the productivity of cashew tree (Anacardium occidentale L.) by producers in N'Dali Commune. End of training report for the graduation of Professional degree in environmental management. 2015-2016

Balogoun I., Saïdou A., Ahoton E. L. Amadji G, L., Ahohuendo C. B., Adebo J. B., Babatoundé S., Chougourou D., Adoukonou S. H., Ahanchédé. 2014. Characterization of cashew-based production systems in the main growing areas in Benin. African Agronomy 26 (1): 1 -14.

Beaumont, L. J., Graham, E., Duursma, D. E., Wilson, P. D., Cabrelli, A., Baumgartner, J. B., Hallgren, W. et al. (2016). "Which Species Distribution Models Are More (or Less) Likely to Project Broad-Scale, Climate-Induced Shifts in Species Ranges?" Ecological Modelling 342: 135-46. https://doi.org/10.1016/j.ecolmodel.2016.10.004.

Elith, J., Phillips, S. J., Hastie, T., Dudik, M., Chee, Y. E. & Yates, C. J. (2011). "A Statistical Explanation of MaxEnt for Ecologists". Diversity Distrib 17: 43-57.

FAO, 2014. FAO database 2011. http://faostat3.fao.org

Feng, F., Park, D., Liang, Y. & Papes, M. (2019). "Collinearity in Ecological Niche Modeling: Confusions and Challenges". Ecol Evol, 9:10365-10376. https://doi.org/10.1002/ece3.5555. www.ecolevol.org

Jayathilaka P.M.S., Soni P., Perret S., Jayasuriya H.P.W.and Salokhe V.M. 2012. Spatial assessment of climate change effects on crop suitability for major plantation crops in Sri Lanka. Regional environmental change: 55-68.

Phillips, S. J., Anderson, R. P. & Schapire, R. E. (2005). "Maximum Entropy Modeling of Species Geographic Distributions". Ecological Modelling 190 (2006) 231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026.

Sauer J. D., 1993. Historical geography of crop plants:a selected roster. CRC Press, Mexico, 320p

Sivagurunathan P., Sivansankari S., Muthukkaruppan S. M., 2010. Characterisation of cashew apple (Anacardium occidentale L.) fruits collected from Ariyalur District. Journal of Bioscience Research,1: 101-107

Tandjiékpon A. M., 2010. Value chain analysis of the cashew sector in Benin. Study report, African Cashew Initiative (ICA/GIZ), Benin, 62p.

Tchétangni Y. A. AssogbadjoA. E. & Houéhanou T. 2016. Perception Paysanne Des Effets Du Changement Climatique Sur La Production Des Noix D'anacardier (Anacardium Occidentale L.) Dans la Commune de Savalou Au Bénin. European Scientific Journal .12 (14) ISSN: 1857 - 7881. doi: 10.19044/esj.2016.v12n14p220

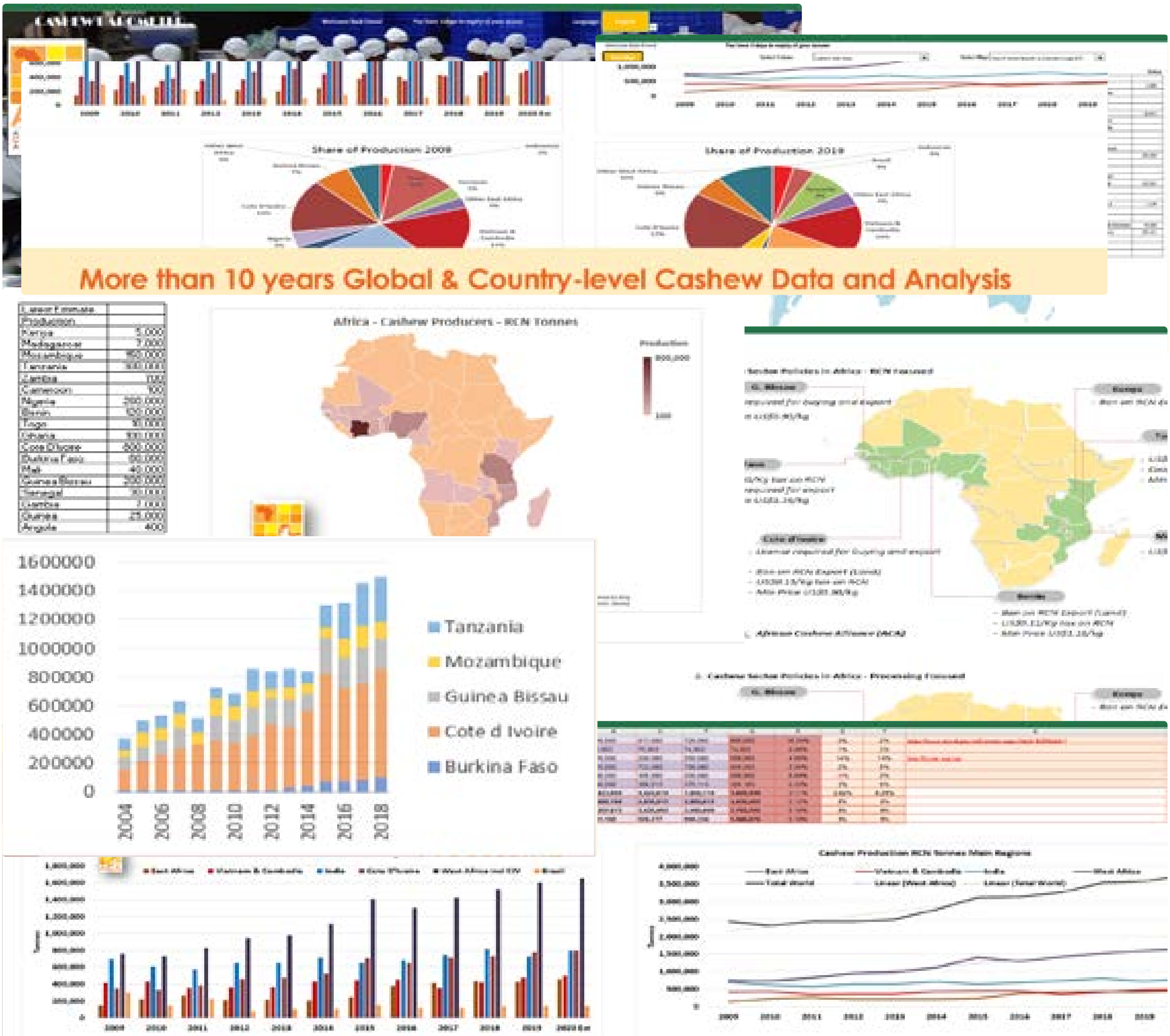
Warren, D. L., Richard, E. G. & Turelli, M. (2010). "ENMTools: A Toolbox for Comparative Studies of Environmental Niche Models." Ecography 33: 607-611. https://doi.org/10.1111/j.1600-0587.2009.06142.x.

Yabi I., Biaou F.Y., Dadegnon S. 2013. Plant species diversity within cashew-based agroforests in the commune of Savalou, Benin, International Journal of biological and Chemical Sciences 7(2): 696-706.

Yabi I. 2008. Study of cashew agroforestry and climatic constraints to its development in central Benin, 240p.

Zonneveld, M. van., Koskela, J., Vicenti, B. & Jarvis, A. (2009). "Impact of Climate Change on the Distribution of Tropical Pines in Southeast Asia". Unasylva 231/232 (60): 2429 .

Cashew Barometer



Register as ACA Member or Subscribe

For more than 10 years Global & Country-level Cashew Data and Analysis, covering:

- Production Area, Volumes and Quality
- Processing Volumes, Utilized Capacities
- Price Data (RCN, Kernel)
- Export Trade Volumes
- Import Trade Volumes
- Sector Organization and Regulation Information

This document has been reproduced with the support of the United States Department of Agriculture (USDA) through the USDA West Africa PRO-Cashew project.

facebook.com/africancashewalliance
twitter.com/africancashewalliance
youtube.com/africancashewa
linkedin.com/company/african-cashew-alliance
www.africancashewalliance.com
African Cashew Alliance Secretariat, 34 Boundary Road, East Leon, Accra, Ghana