

(RESEARCH ARTICLE)



MARKET QUALITY ANALYSIS OF CASHEW NUTS (*ANACARDIUM OCCIDENTALE* L.) PRODUCED IN THE NIOFOIN SUBPREFECTURE (NORTHERN CÔTE D'IVOIRE)

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ABSTRACT

The quality of cashew nuts is an important factor in their marketing. However, data on nut quality are largely unavailable in Côte d'Ivoire. The aim of this study was to assess the quality of cashew nuts in the Niofoin subprefecture. To this end, 45 cashew nut samples were collected from 225 producers across 15 localities in the Niofoin subprefecture. The quality of the cashew nuts in each sample was assessed by determining moisture content, foreign matter content, grain size, defect rate, and the Kernel Output Ratio (KOR). The cashew nuts were classified into quality grades according to the criteria defined by the Ivorian standard.

The average values of the parameters studied were $7.22 \pm 1.33\%$ for moisture content, $0.24 \pm 0.01\%$ for foreign matter content, 186.27 ± 2.45 nuts/kg for grain size, $13.07 \pm 1.68\%$ for the defect rate, $26.95 \pm 0.63\%$ for the kernel yield, and 47.43 ± 1.11 lb for the KOR. Considering only moisture content, grain size, and impurities, all cashew samples were classified as Grade I. However, when all six quality parameters were taken into account, 80% of the cashew samples were classified as grade II, 17.78% as grade III, and 2.22% as grade I. Thus, the market quality of cashew nuts produced in the Niofoin subprefecture is moderately good.

Keywords: Cashew Nuts, Grain Size, KOR, Defect Rate, Niofoin, Côte d'Ivoire

1 INTRODUCTION

The cashew tree (*Anacardium occidentale* L.) is a perennial plant that was introduced to Côte d'Ivoire around 1960 as a reforestation tree to combat soil erosion in the northern part of the country [1]. Thus, during the first few decades after the cashew tree was introduced to Côte d'Ivoire, neither the cashew nut nor the cashew apple was sold commercially [2]. It was around 1990, with strong demand on the international market for the fruits of the cashew tree, known as cashew nuts, that the cultivation of this plant as a commercial crop began [3], [4]. The country's annual cashew nut production has gradually increased from 8,500 metric tons in 1989 to 70,000 metric tons in 1999 [5], [6]. From 2012 to 2022, cashew nut production in Côte d'Ivoire increased from 450,000 metric tons to 1,028,172 metric tons [7]. Since 2015, Côte d'Ivoire has been the world's leading producer and exporter of cashew nuts. As a result, since 2000, Cashew nuts have become one of Côte d'Ivoire's main export products and contribute significantly to the country's socioeconomic development [8].

Despite the significant increase in production, several challenges remain that must be addressed to ensure more successful marketing for the benefit of the different stakeholders [9]. In fact, producers and traders set the price of cashew nuts based only on their size, shape, color, and luster [10]. These criteria used to assess the quality of Cashew nuts are not very accurate. In fact, Cashew nuts are sold for the kernels they contain. However, the correlation between the quality of the kernels inside the nuts and these criteria is not very strong. [10]. The Kernel Output Ratio (KOR) is the key factor determining the quality of cashew nuts [11]. The KOR is the ratio of the weight of usable kernels to the total estimated weight of the nuts, calculated from a one-kilogram sample and expressed per 80-kilogram bag [12]. Consequently, assessing the quality of cashew nuts is an important factor in their marketing. However, data on the quality of cashew nuts are scarce in Côte d'Ivoire in general and in the Niofoin subprefecture in particular. That is why this study was conducted with the aim of assessing the quality of cashew nuts in the Niofoin subprefecture.

2 MATERIALS AND METHODS

2.1 Study area

The study was conducted in the Niofoin subprefecture, located in northern Côte d'Ivoire (Figure 1). The climate is dry tropical, characterized by a dry season and a rainy season. The dry season begins in November and ends in May. The rainy season begins in June and lasts through October, with the heaviest rainfall occurring in August [13]. The relief is characterized by a succession of hills and plains, dominated by plateaus ranging in elevation from 100 to 200 meters. The subprefecture of Niofoin is located in the subsudanian phytogeographic region of Côte d'Ivoire [14]. Natural vegetation types include wooded savannas, shrubby savannas, dense dry forests, and open forests [15]. The main economic activity of the people in the Niofoin Subprefecture is agriculture. Cotton (*Gossypium* sp.) and cashew (*Anacardium occidentale* L.) are the commercial crops cultivated by the local population.

2.2 Materials

The materials used to conduct this study included:

- cashew nuts collected from producers to determine their quality;
- a probe for taking samples of cashew nuts from the bags;
- an electronic scale accurate to 0.5 g for weighing the samples;
- small plastic buckets to store the samples to be analyzed;
- a portable moisture meter to determine the moisture content of the samples;
- bags to collect impurities (leaves, pebbles, dried apples, twigs, etc.) present in the samples;
- latex gloves to protect the hands when handling the nuts;
- a calao beak-shaped plier to open the nuts;
- a needle to separate the kernel from the shell;
- green, blue, and red plastic cups to hold, respectively, sound nuts, nuts accepted (or rejected) at 50%, and nuts rejected at 100%;
- data sheets for recording data.

2.3 Sampling of cashew nuts

The cashew nuts were collected from 225 producers across 15 localities in the Niofoin subprefecture. From each producer, 1 kg of cashew nuts was sampled using a probe from a randomly selected bag. Thus, 15 kg of cashew nuts were sampled from each village. This quantity of nuts (15 kg) was piled on a flat surface, thoroughly mixed, and divided into three batches (samples) of 5 kg each.

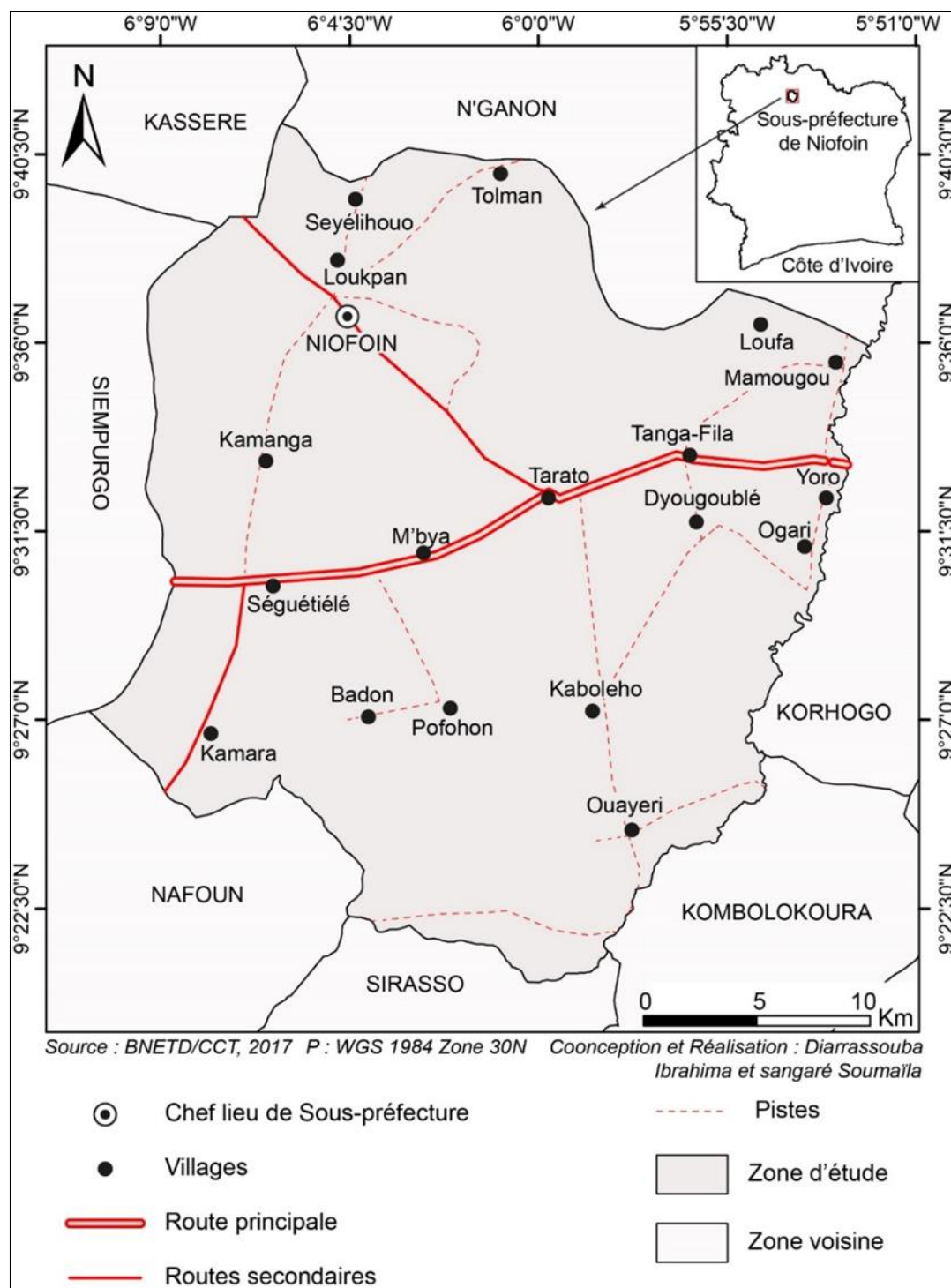


Figure 1: Location of the Niofoin subprefecture

Table 1: Number of producers and cashew nuts samples by locality

Localities	Number of producers	Number of cashew nuts samples
Kamara	15	3
M'bia	15	3
Seguétélé	15	3
Tangafla	15	3
Tarato	15	3

Djougoublé	15	3
Loufa	15	3
Ogari	15	3
Pivonhon	15	3
Tchangaton	15	3
Kanihoua	15	3
Mara	15	3
Somon	15	3
Tolman	15	3
Yoro	15	3
Total	225	45

2.4 Determination of cashew nut quality parameters

2.4.1 Moisture content

The moisture content of the cashew nuts was determined in accordance with the Ivorian standard using a Dickey John Mini Gac Plus portable moisture meter. [16], [17]. After calibrating the moisture meter, a few nuts were placed in the device at room temperature. The moisture content (in %) was shown automatically after pressing the measurement button on the device.

2.4.2 Foreign matter content and grain size

The foreign matter content and grain size of cashews were determined using the method described by [18]. The foreign matter content was calculated using the following formula:

$$\text{Foreign matter content (\%)} = \frac{\text{Mfm}}{\text{Mt}} \times 100$$

Where Mfm is the mass, in grams, of foreign matter extracted from a representative sample of one kilogram of cashews; Mt is the initial total mass of the representative sample of cashews, which is 1000 g.

Cashew nuts meet commercial cleanliness standards when the foreign matter content is less than 0.5%.

As for grain size, it was determined by counting the exact number of cashew nuts in a one-kilogram sample free of foreign matter. The lower the grain size value, the larger and heavier the nuts are, and therefore the higher their quality.

2.4.3 Defect rate, kernel yield, and Kernel Output Ratio

The defect rate, kernel yield, and Kernel Output Ratio (KOR) of cashew nuts were determined gravimetrically using the method described by [18]. The steps in this method are inspecting and classifying the kernel, weighing the different categories of nuts, calculating the defect rate, calculating the kernel yield, and calculating the KOR.

To inspect and grade the kernels, a representative sample of one kilogram of Cashew nuts was weighed. Wearing a pair of gloves and working in a well-lit area, all the Cashew nuts in the sample were carefully cut in half lengthwise using a pair of calao-beak pliers. During this process, the two halves of each nut were kept together; the kernels were not separated from the shells; and the pliers were cleaned after each cut. Next, the halved walnuts were examined to assess the state of the kernels and classify them into three categories according to the criteria in [19] presented in Figure 2. The three categories are:

- good-quality nuts (white, intact, and free of visible defects), which are fully usable and constitute the “green” category, 100% of which are accepted;
- immature nuts (wrinkled kernels) and spotted nuts (with at least one black spot or black mark on the kernel), which are partially usable, constitute the blue category, 50% of which is accepted (or rejected);
- buttery, moth-eaten, stunted, moldy, and empty nuts make up the red category, which is 100% rejected.

As for weighing the different categories of nuts, this step was carried out in several phases. Starting with the nuts in the “green” category, the good kernels were separated from their shells using a needle. These kernels and their skins were placed together on one side, and the shells on the other side. These good kernels (100% accepted) and their skins were placed in the green tray and then weighed. The total mass of the good kernels and their skins was recorded as M_2 .

The immature or damaged nuts in the blue category were weighed. The total mass of these nuts (kernels + shells) accepted at 50% was recorded as M_3 . Next, the immature or damaged kernels were separated from their shells. These kernels, accepted at 50%, along with their skins, were placed in the blue tray and then weighed. The total mass of the kernels accepted at 50% and their skins was recorded as M_4 . Similarly, nuts in the red category that had defects (buttery, worm-eaten, stunted, musty or empty nuts) were placed in the red tray and then weighed. The total mass of nuts (kernels + shells) that were 100% rejected was recorded as M_5 .

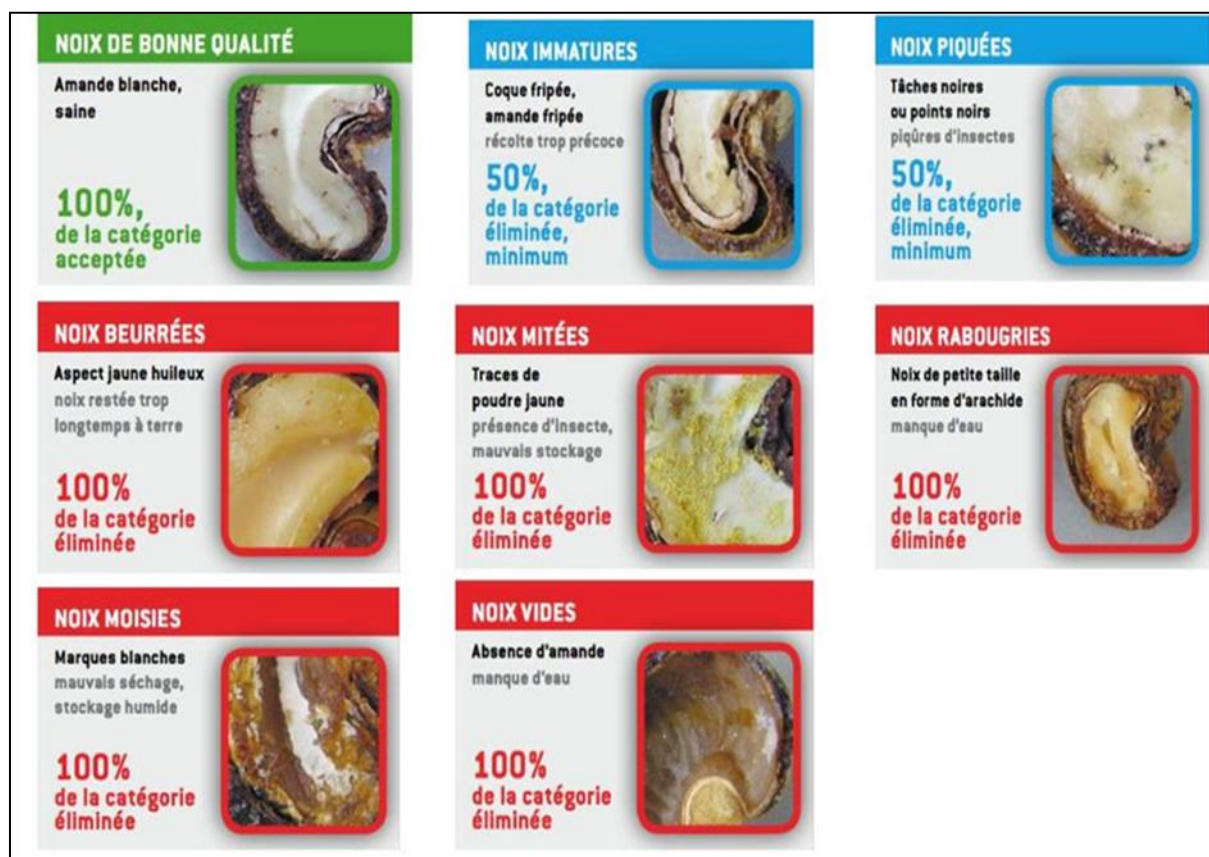


Figure 2: Criteria for classifying cashew nuts in quality control analysis

The defect rate for cashew nuts is the ratio, expressed as a percentage, of the mass of defective nuts to the total mass of the sample. The defect rate was calculated using the following formula:

$$\text{Defect rate (\%)} = \frac{M_3 + M_5}{M_1} \times 100$$

Where:

- M_1 is the total mass of the cashew nut sample (1000 g);
- M_3 represents the total mass in grams of the nuts (kernels + shells) rejected at 50%;
- M_5 is the total mass in grams of the nuts (kernels + shells) rejected at 100%.

The kernel yield of cashew nuts refers to the percentage of eatable kernels that can be obtained after shelling a given quantity of cashews nuts. The kernel yield was calculated using the following formula:

$$\text{Kernel yield (\%)} = \frac{M_2 + \frac{M_4}{2}}{M_1} \times 100$$

Where:

- M_1 is the total mass of the cashew nut sample (1000 g);
- M_2 represents the total mass in grams of kernels accepted at 100% and their skins;
- M_4 is the total mass in grams of kernels accepted at 50% and their skins.

The Kernel Output Ratio (KOR) indicates the quantity of usable kernels that can be extracted from a standard 80-kg bag of cashew nuts. The KOR was calculated using the following formula:

$$\text{KOR (lb)} = \left(\frac{\text{KY}}{100} \right) \times 80 \times \left(\frac{1}{0.45359} \right)$$

Where KY is the kernel yield and 1/0.45359 is the conversion factor from kilograms (kg) to British pounds (lb).

The quality of cashew nuts is:

- poor if the KOR is less than 40 lbs;
- marginal when the KOR is between 40 lbs and 46 lbs;
- good (commercial standard) when the KOR is between 47 lbs and 50 lbs;
- excellent if the KOR is greater than 50 lbs.

2.5 Grade classification of cashew nuts

Cashew nuts were classified by grade according to the quality criteria (Table 2) of the Ivorian standard [16], [17]. Thus, the samples were graded according to these criteria for each quality parameter determined. Next, the overall quality of the samples was assessed based on the results of the six parameters determined (moisture content, foreign matter content, grain size, defect rate, kernel yield, and KOR).

Table 2: Criteria for the market quality of cashew nuts

Quality parameters	Grade I	Grade II	Grade III
Moisture content (%)	≤ 10	≤ 10	≤ 10
Foreign matter content (%)	≤ 0.5	≤ 0.5	≤ 0.5
Grain size (nuts/kg)	≤ 200	]200; 215]	]215; 240]
Defect rate (%)	≤ 10	]10; 15]	]15; 20]
Kernel yield (%)	≥ 27.24	[23.83; 27.23]	[19.86; 23.82]
Kernel Output Ratio (lb)	≥ 48	]42; 48[	[35; 42]

The overall quality of a cashew sample was classified as:

- grade I, when all six quality parameters satisfied the criteria for grade I;
- grade II, when at least one quality parameter satisfied the criteria for grade II and the other parameters satisfied the criteria for grade I;
- grade III, when at least one quality parameter met the criteria for grade III and the other parameters satisfied the criteria for grade I or grade II.

2.6 Data processing

The data from the report sheets were entered into an Excel spreadsheet. Pivot table reports were used to provide information on:

- the values of cashew quality parameters (moisture content, foreign matter content, grain size, defect rate, kernel yield, Kernel Output Ratio);
- the classification of cashew nut samples by grade based on each quality parameter;
- the classification of cashew nut samples by grade based on their overall quality.

For each quality parameter, the minimum value, maximum value, mean, and standard deviation were determined. For a GX quality grade, the proportion of samples (PS) was calculated using the following formula:

$$\text{Proportion of samples (PS) (PE)} = \frac{\text{Number of samples classified as GX}}{\text{Total number of samples analyzed}}$$

3 RESULTS

3.1 Quality parameter values for cashew nuts

Table 3 summarizes the average values of the quality parameters for cashew nuts. The moisture content of the cashew nut samples ranged from 6.00% to 10.00%, with an average of $7.22 \pm 1.33\%$. The foreign matter content ranged from 0.20% to 0.26%, with an average of $0.24 \pm 0.01\%$. As for the grain size, the minimum value was 178 nuts/kg and the maximum value was 189 nuts/kg. The average grain size was 186.27 ± 2.45 nuts/kg. The defect rate of the cashew nut samples ranged from 10.00% to 16.80%. For this parameter, the average was $13.07 \pm 1.68\%$. Regarding kernel yield, the values ranged from 25.30% to 28.00%, with an average of $26.95 \pm 0.63\%$. Regarding the kernel output ratio, the minimum value was 44.53 lb and the maximum value was 49.28 lb. The average kernel output ratio was 47.43 ± 1.11 lb.

Table 3: Quality parameter values for cashew nut samples

Quality parameters	Minimum value	Maximum value	Mean $\pm$ standard deviation
Moisture content (%)	6.00	10.00	7.22 ± 1.33
Foreign matter content (%)	0.20	0.26	0.24 ± 0.01
Grain size (nuts/kg)	178	189	186.27 ± 2.45
Defect rate (%)	10.00	16.80	13.07 ± 1.68
Kernel yield (%)	25.30	28.00	26.95 ± 0.63
Kernel Output Ratio (lb)	44.53	49.28	47.43 ± 1.11

3.2 Classification of cashew nut samples in grades based on each quality parameter

The distribution of cashew samples across grades based on each quality parameter studied is shown in Figure 3. For moisture content, foreign matter content, and grain size, all samples were classified as grade I. Regarding defect rate, the majority of samples (80%) were classified as grade II. Grade II samples were followed by those in grade III, which accounted for 17.78%. With 2.22% of the samples, grade I was the least represented. Regarding kernel yield and KOR, samples classified as grade II constituted the highest proportion (62.22%). The remaining samples (37.78%) were classified as grade I.

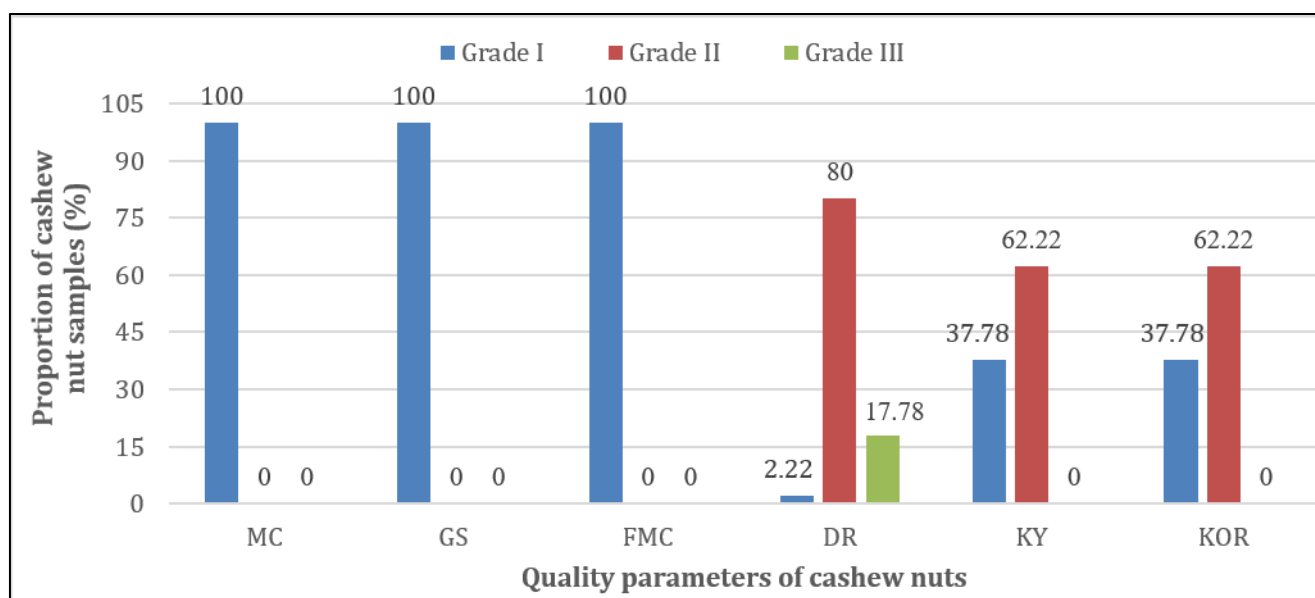


Figure 3: Distribution of cashew nut samples by grade and parameter

MC: Moisture Content; GS: Grain Size; FMC: Foreign Matter Content; DR: Defect Rate; KY: Kernel Yield; KOR: Kernel Output Ratio

3.3 Classification of cashew nut samples by grade based on their overall quality

The distribution of cashew samples across grades based on their overall quality is shown in Table IV. At 80%, samples classified as grade II constituted the majority. Grade II samples were followed by those in grade III, which accounted for 17.78%. Grade I was the least represented, accounting for 2.22% of the samples. In assessing the overall quality of the cashew nuts, the defect rate was the quality parameter responsible for classifying samples into grade III.

Table 4: Distribution of cashew nut samples by grade

Grades	Proportion of cashew nut samples (%)
I	2.22
II	80.00
III	17.78

4 DISCUSSION

This study evaluated the quality of cashew nuts in the Niofoin subprefecture. The study revealed that the moisture content of the cashew nuts ranged from 6.00% to 10.00%. These values, which are less than or equal to 10%, indicate that the moisture content of all cashew nut samples collected are of satisfactory quality in accordance with the Ivorian standard. [16], [17]. This would mean that producers in the area are drying their cashew nuts correctly. According to [20], drying is an important step in the post-harvest processing of cashew nuts. However, 21 samples (46.47% of the samples analyzed) had a moisture content of 6%, which is below 7%. Yet, according to several authors, the equilibrium moisture content of cashews is between 7% and 10% [19], [21]. Thus, marketing cashew nuts with a moisture content below 7% would result in a loss of mass, which in turn would mean a loss of revenue. Furthermore, shelling nuts that are too dry leads to a high rate of kernel breakage, thereby reducing their commercial value [2], [22].

The foreign matter content ranged from 0.20% to 0.26%. Thus, the foreign matter contents determined were all below 0.5%, which is the threshold specified by the Ivorian standard [16], [17]. This result could be explained by the fact that producers in the area remove foreign matter from their cashew nuts. The majority of foreign matter is probably removed during the drying of the cashew nuts [20].

Regarding grain size, the values obtained ranged from 178 nuts/kg to 189 nuts/kg. These values, which are below 200 nuts/kg, indicate that the grain size of all the cashew nut samples collected is satisfactory in accordance with the Ivorian standard [16], [17]. Indeed, these grain size values below 200 nuts/kg indicate that the nuts are large, heavy, and therefore of higher quality [23]. These grain size values are similar to those obtained by [20] in the Korhogo Department (Côte d'Ivoire), which ranged from 179 nuts/kg to 182 nuts/kg. The average grain size in this study (186 nuts/kg) is higher than the national average grain size for the 2017-2018 and 2018-2019 growing seasons. In fact, according to [20], the national average grain sizes were 190 nuts/kg in 2017-2018 and 192 nuts/kg in 2018-2019. For these crop years (2017-2018 and 2018-2019), average grain size similar to that of this study (186 nuts/kg) was obtained in Benin. In Benin, the national average grain size for the 2017-2018 and 2018-2019 crop years were 184 nuts/kg and 187 nuts/kg, respectively [20]. In some West African countries, such as Burkina Faso and Ghana, the average grain size were lower than those in this study (186 nuts/kg). In fact, the average grain size were 198 nuts/kg in 2017-2018 and 199 nuts/kg in 2018-2019 in Burkina Faso. In Ghana, they were 195 nuts/kg in 2017-2018 and 198 nuts/kg in 2018-2019. However, these grain size values meet the market quality criteria for Grade I cashews (grain size less than 200 nuts/kg), as do those in this study (186 nuts/kg).

Furthermore, during the same periods, grain size values that met the marketability criteria for grade II cashew nuts (grain size values ranging from 200 nuts/kg to 215 nuts/kg) were obtained in The Gambia, Guinea-Bissau, and Senegal, according to [24]. In fact, in The Gambia, grain sizes were 208 nuts/kg in 2017-2018 and 202 nuts/kg in 2018-2019. In Guinea-Bissau, the grain sizes were 215 nuts/kg and 222 nuts/kg in 2017-2018 and 2018-2019, respectively. In Senegal, the grain sizes for the 2017-2018 and 2018-2019 crop years were 218 nuts/kg and 227 nuts/kg,

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According to [26], there was a significant difference between the average grain sizes of plots receiving adequate maintenance (150 nuts/kg) and that of plots without maintenance (163 nuts/kg) in the Borgou Department (Benin).

The defect rates ranged from 10.00% to 16.80%, with an average of $13.07 \pm 1.68\%$. For the majority of the samples (80%), the defect rate ranged from 10% to 15% (the marketability criteria for grade I cashew nuts). Samples with a defect rate between 15% and 20% (the market quality criteria for grade III cashews nuts) accounted for 17.78% of the total. Only 2.22% of the samples met the market quality criteria for grade I cashews nuts (a defect rate of 10% or less). Thus, all cashew nut samples in this study had defect rates exceeding 8%, which is the upper limit for good-quality cashew nuts according to the UEMOA standard [27].

In Casamance (Senegal), defect rates lower than those in this study were reported by [11]. In fact, defect rates ranging from 7.5% to 10.6% were reported by [11] in the localities of Ziguinchor, Sédhiou, and Kolda. The average defect rate in this study (13.07%) is similar to the national average defect rates for the 2017-2018 and 2018-2019 growing seasons. In fact, according to [20], the national average defect rates were 12.7% in 2017-2018 and 13.1% in 2018-2019. The relatively high defect rates in this study could be explained by poor harvesting practices, post-harvest handling, and attacks on developing fruits by insect pests [28]. Indeed, picking fruits from cashew trees results in the harvest of immature nuts [16], [17], [29]. The recommended harvesting practice is to allow mature fruits to fall on their own and then collect them. Furthermore, delayed fruit collection results in buttery nuts [16], [17], [21]. To avoid buttery nuts, the interval between harvests on the same plot should not exceed three days. Attacks on developing fruits by insect pests are responsible for pitted and moth-damaged nuts [20]. Sustainable plant protection measures could help prevent pitted and moth-damaged nuts.

The determined kernel yields ranged from 25.30% to 28.00%, with an average of $26.95 \pm 0.63\%$. The majority of the samples (62.22%) had a kernel yield falling within the range [23.83%; 27.23%]. Thus, 62.22% of the samples met the market quality criteria for grade II cashew nuts. For the remaining samples (37.78%), the kernel yield was greater than or equal to 27.24% (market quality criteria for grade I cashew nuts). The kernel yield values in this study are similar to those obtained by [11] in Senegal. In fact, kernel yields ranging from 23.57% to 28.34% were reported by [11] in the localities of Bignona, Bounkiling, Goudomp, Kolda, Medina Yoro Fouta, Oussouye, Sédhiou, Vélingara, and Ziguinchor (Senegal).

Regarding the Kernel Output Ratio, the values ranged from 44.53 lb to 49.28 lb, with an average of 47.43 ± 1.11 lb. Samples with a Kernel Output Ratio falling within the range [42 lb; 48 lb], and thus met the market quality criteria for grade II cashew nuts, accounted for 62.22%. Less than half of the samples (37.78%) had a Kernel Output Ratio value greater than or equal to 48 lb (the market quality criteria for grade I cashew nuts). In the Sédhiou and Ziguinchor regions (Senegal), average Kernel Output Ratio values better than those of the present study (47.43 lb) were obtained by [11]. In fact, the average Kernel Output Ratio values reported by [11] ranged from 48 lb to 50.9 lb. However, the average Kernel Output Ratio value in this study (47.43 lb) is higher than that obtained (45.42 lb) by [20] in the Korhogo department.

5 CONCLUSION

Understanding the quality of cashew nuts is essential for the successful marketing of this agricultural product. The aim of this study was to assess the quality of cashew nuts in the Niofoin subprefecture. The results show that the cashew nuts produced were generally well-dried, large in size, and contained very few foreign materials. However, when all quality parameters were taken into account, the majority of cashew nut samples were classified as grade II (80%) and grade III (17.78%) due to their defect rate. The results obtained provide baseline data that can be used to guide awareness-raising activities for producers on the application of good agricultural, harvesting, and postharvest practices with a view to improving the quality of the cashew nuts produced.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest related to this research article.

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