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STUDY OF CASHEW NUTS VARIABILITY AND PROPOSITION OF AN ANALYTICAL METHOD

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ABSTRACT

Cashew nuts are appreciated worldwide. Nevertheless, no official method for its quality determination exits. The aim of this study is to appreciate this quality in time and to propose eventually a method for quality determination.
It clearly appeared that, for 1999 and 2000, the quality parameters (immature, mouldy, stung and partially damaged and empty nuts) vary whereas, others like nut count do not present any significant ($p>0.05$) variation. In addition, empty and mouldy nuts were shown to be the major factors in nut quality depreciation.
The correlation coefficient analysis points out that the different quality parameters can be divided into three groups according to their causes: nut count, empty and immature nuts of physiological origin; mouldy, stung and partially damaged nuts of fungal origin and stunted and buttered nuts which have no evident relationship with the other parameters.
Sampling method with a sample size of 400 nuts and a linear analytical method were proposed and proven more accurate and easy to use.

KEY WORDS: Cashew nuts; sampling method; efficiency curve; quality parameters

INTRODUCTION

The Cashew tree (*Anacardium occidentale L*) is a plant originating from Brazil. It was implanted in eastern and western Africa during the second half of the 16th century. Today its culture is located in almost all the hot zones of the earth (Ministère de la Cooperation, 1993). It is a plant whose fruit is composed of two parts: the almond and the apple. The former which represents about 20 to 30 per cent of the fruit is the part industrially exploited (Alves *et al.*, 2001; Garruti *et al.*, 2003). It is sold throughout the world (United States, India, Japan...) under various appearances (butters, roasted almonds...) (Prodi *et al.*, 1994; Promexa, 1997). However, in spite of this interest, no official method of determination of the cashew nut quality exists (Normalisation ivoirienne 2001a, Normalisation ivoirienne 2001b).
The purpose of this work is firstly to study the variability in time of the cashew nut quality and secondly to test performances of the existing analytical method in order to propose, if necessary, another one.

MATERIALS AND METHODS

Biological material

The cashew nuts studied were purchased from different markets in Côte d'Ivoire (Ivory Coast) per 80 kg weighting bags. At each delivery, 375 bags were ordered.
The analysis of cashew nuts was carried out after sampling, with the help of conic probes, on about 20% of the bags received. The samples drawn were mixed then, separated by the opposite quarter method. This method consists in dividing the sample in four parts, with the help of a metal cross, and choosing two opposite parts. A sample of 5 kg was taken to the laboratory for analysis. With the same opposite quarter method, a sample of 1 kg was removed and stored. Finally, nuts of this sample were counted to determine their number. Then, they were cut longitudinally with the help of special scissors and were classified according to the different defects observed (as summarised in table 1). Every category was weighted and the weight of usable almond (outturn) per bag (80 kg) was determined according to the following equation (Promexa, 1997):

$$\text{Weight of usable almond} = 0.1764(A + 0.5B)$$

With A as the healthy almond weight, and B as the weight of the defective almond.

Variability Study

This study was operated on samples drawn in 1999 (578) and those (314) of 2000. Each test was made in triplicate. Different statistical calculations (average, standard deviation...) were made using spreadsheets programmed on Excel 2000 (Microsoft Inc., St-Quentin, France).

Assessment of the actual analytical method performances

Performances of the analysis method used for outturn assessment were determined via its fidelity (repeatability and reproducibility) and its fitness (Feinberg, 1996). These parameters have been deeply studied elsewhere (Bouroche and Saporta, 1992; Dagnelie, 1975; Feinberg, 1996). In this study, these statistical parameters were drawn according to ISO 5725 norm (International Standardisation Organisation, 1994)
The fitness was estimated through the Mandel *h* and *k* statistics (Feinberg, 1996; International Standardisation Organisation, 1994; Sokal *et al.*, 1995).

Efficiency Curve of a sampling plan

The efficiency curve enables to appreciate the quality of a sampling plan to discriminate correctly a good batch from a

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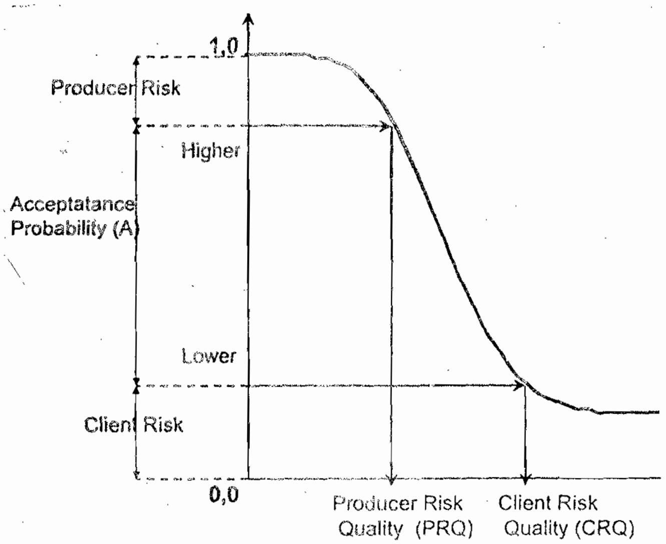

Figure 1: A sampling plan efficiency curve

bad one. It represents the relationship between the proportion of non acceptable individual p and probability p_a of a batch to be accepted. This relationship, as shown in figure 1, is sigmoid and depends on n (the sample size) and A (the acceptance criterion). The French norm X 06-018 (Agence de Normalisation Française, 1994) defines terms associated to this efficiency curve. To summarize, while the producer risk (*PR*) constitutes the risk to refuse a batch whereas it is of good quality, the client risk (*CR*) is, on the contrary, the one to accept a bad quality batch. To these different risks are associated different qualities to the producer risk (*PRQ*) and to the client risk (*CRQ*) respectively.

The discrimination ratio (*DR*) is the ratio between the client risk quality (*CRQ*) to the producer risk one (*PRQ*). The plan is more selective, if the ratio is closer to 1 (Agence de Normalisation Française, 1987; Agence de Normalisation Française, 1994; Tassi, 1989).

RESULTS AND DISCUSSION

Quality variability

Quality variability was studied using samples from 1999 (578 samples) and 2000 (314 samples). The results obtained are represented in figure 2.

It appears that empty nuts are distinguishable from other defects by a constant proportion during both years. On the other hand, the other defects are different from one year to the other. This level of variability is not astonishing when one knows that these nuts are from different geographical origins, different cultivars and are collected at different dates. But, is this difference statistically significant?

In order to answer to this question, comparison was made and the results are summarised in table 2.

It can be observed that no significant difference ($p<0.05$) appears between empty nuts obtained in 1999 and those of 2000 (table 2). On the other hand, while one can observe a significant difference ($p>0.05$) between averages of the stunted nuts, this difference is highly significant ($p>0.01$) for parameters like the nuts count and very highly significant ($p>0.001$) for the others (e.g. immature, stung, moth-eaten and mouldy nuts, outturn). The outturn obtained in 1999 is higher than that of 2000. In addition, the outturns obtained during both years are superior to the minimum usually needed (44.00).

B: •, does a relationship exist between the different defects and the outturn?

Table 1: Different category of almond defects

Defects	Definition
Empty nuts	Empty shell, without almond
Moth-eaten nuts	Almond transformed in powder or gnawed by bugs
Mouldy nuts	Development of moulds giving a dark black, brown or yellow coloration
Buttered nuts	Almond impregnated with balm that gives it a fatty aspect
Stunted nuts	Atrophied almond, crumpled
Immature nuts	Almond whose growth is not yield, presenting a wrinkled aspect and incompletely formed
Stung nuts	Almond with some small black spots on its surface
Partially damaged nuts	Almond with minor defects others than those mentioned

Table 2: Quality parameters comparison for 1999 and 2000

Quality Parameters	Mean	SD	Means Comparaison
Nuts count-99	203.0	15.0	**
Nuts count-00	200.0	10.0	
Empty nuts-99	26.5	19.1	no significant difference
Empty nuts-00	25.8	15.8	
Moth-eaten nuts-99	7.9	9.0	***
Moth-eaten nuts-00	3.0	6.0	
Mouldy nuts-99	44.2	35.7	***
Mouldy nuts-00	63.6	41.2	
Buttered nuts-99	14.3	13.8	***
Buttered nuts-00	18.2	17.6	
Stunted nuts-99	0.5	3.1	*
Stunted nuts-00	0.1	1.0	
Immature nuts-99	19.7	16.8	***
Immature nuts-00	14.3	12.6	
Stung nuts-99	26.1	20.1	***
Stung nuts-00	41.1	25.2	
Partially damaged-99	7.2	14.3	***
Partially damaged-00	11.0	13.7	
Outturn-99	49.3	4.6	***
Outturn-00	47.0	3.4	

NB: * Significant difference ($p>0.05$); ** Highly significant difference ($p>0.01$); *** Very highly significant difference ($p>0.001$)

Table 3: Quality parameters correlation coefficients

Order	Defects	Coefficients (defects effect)	SD	STUDENT t	Significate level
1	Mouldy nuts	-0.648	0.004	15.510	**
2	Empty nuts	-0.091	0.008	-11.200	**
3	Nut Count	0.084	0.009	9.880	**
4	Buttered nuts	-0.090	0.010	-8.710	**
5	Stung nuts	-0.052	0.007	-7.240	**
6	Immature nuts	-0.048	0.009	-5.320	**
7	Partially damaged nuts	-0.045	0.010	-4.410	**
8	Moth-eaten nuts	-0.060	0.016	-3.780	**
9	Stunted nuts	-0.021	0.047	-0.450	non significant
constant		41.490	1.690	24.490	**

Table 4: Repeatability study (SD: standard deviation, RSD: Relative standard deviation)

Sample	Mean value	SD	RSD (%)
1	44.9	1.7	3.8
2	44.4	1.8	4.1
3	45.8	0.9	2.0
4	44.4	1.4	3.2
5	42.7	1.7	4.0
6	37.7	0.9	2.4
7	47.3	0.5	1.1
8	42.5	1.7	4.0
9	42.5	0.9	2.1

Table 5: Reproducibility study

Sample	Mean value	SD	RSD (%)
1	44.9	2.1	4.7
2	44.3	2.2	5.0
3	46.1	1.8	3.9
4	43.8	1.7	3.9
5	44.2	2.4	5.4
6	40.8	1.9	4.7
7	45.3	1.1	2.4
8	39.6	4	10.1
9	41.4	1.2	2.9

In order to point out this eventual relationship, correlation coefficients of defects to the outturn were determined using a linear multiple regression method (Dagnelie, 1975; Drape and Smith, 1988). The results obtained are presented in table 3. Defects are ordered according to the decreasing absolute values of the Student t coefficient obtained.

The analysis of table 3 shows that, apart from stunted nuts, all other quality parameters have a significant ($p>0.01$) influence on the weight of usable almond (outturn). They all influence negatively the outturn, except the nut count. In 2000, the later was 200 nuts, and was not significantly correlated to the outturn. Nevertheless, in 1999, when its value is higher (203 ± 1), it influences the outturn. Thus, it appears that the smallest the nuts, the more improved is the weight of usable almond. This result is in contradiction with the conclusion of the Anacarde 1997 symposium (Promexa, 1997), indicating that when the nut count is lower, nuts are thicker and are usually, expensively sold.

In other respects, it appears that mouldy nuts are the first causes of nuts quality damages, followed by empty nuts. They both represent 22.00 % of quality parameters and induce 64.34% of damage effects.

In addition, if we consider correlation coefficients between parameters, we can observe that the later can be divided into three groups according to their original causes, as follows:

- 1st group: nut count, empty and immature nuts that are physiological defects due to climatic conditions;
- 2nd group: mouldy, stung and partially damaged nuts that are only different stages of development of fungal infection;
- 3rd moth-eaten and buttered nuts caused by bugs and shock respectively.

Characteristics of actual analytical method

Fidelity and exactness of the method

Fidelity and exactness of the commonly used method for the

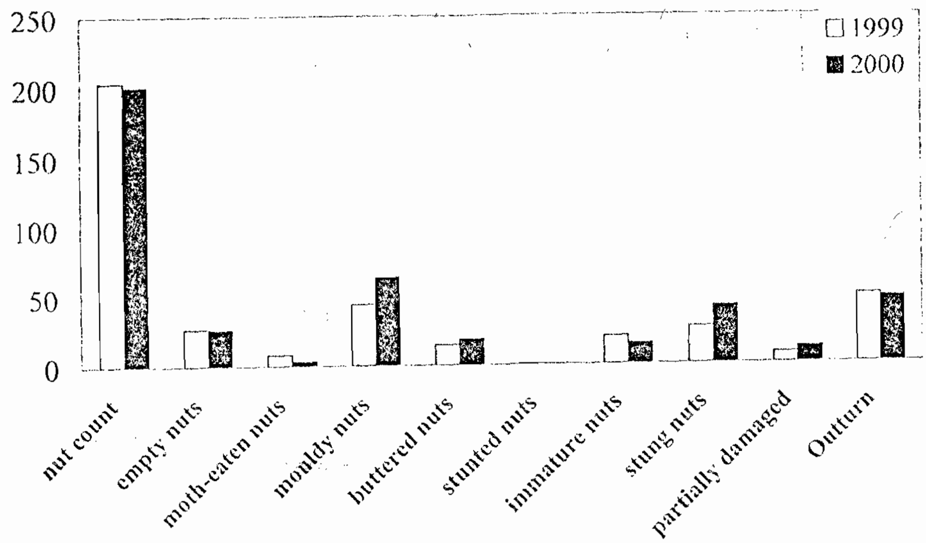

Figure 2: Histogram of quality parameters during 1999 and 2000

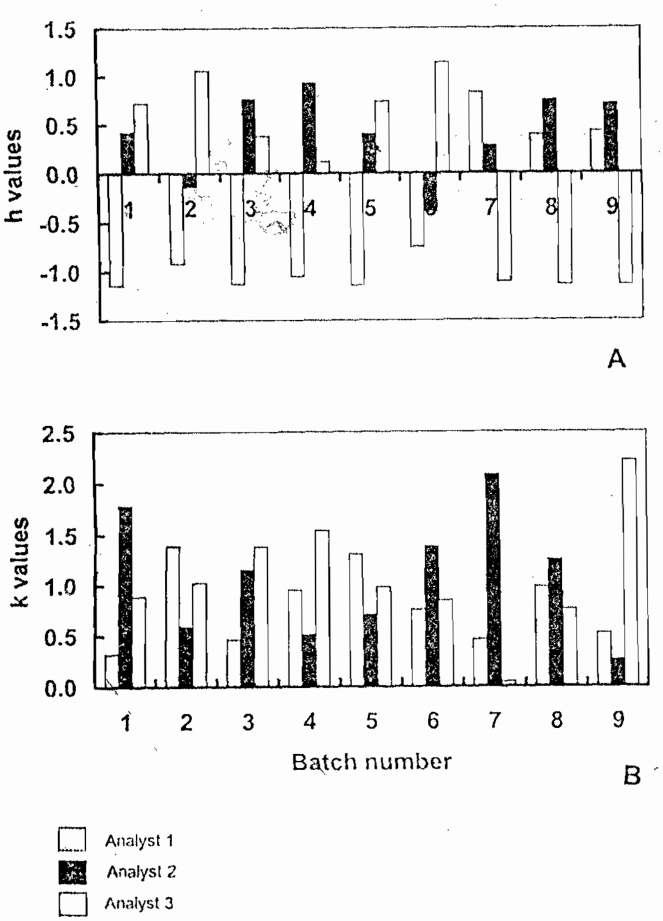

Figure 3: Mandel diagrams for exactness and fidelity studies

(A: Mandel h statistics, B: Mandel k statistics)

determination of cashew nut samples quality were studied. Results concerning the fidelity are summarised in tables 4 and 5, respectively for the repeatability and the reproducibility.

When analysing tables 4 and 5, it appears that relative standard deviation (RSD) values range from 1.10 to 4.10% and from 2.40 to 10.10% respectively for repeatability and reproducibility. These values are all inferior to 15.00%, leading conclusion that the method commonly used is accurate (Cox, 1980; Tomassone and Derwin, 1993).

In accordance with the ISO 5725 norm (International Standardisation Organisation, 1994), the Mandel h and k statistics were determined. Results obtained are presented in figures 3 (A, B) for three different operators. Figure 3 A analysis shows that, whatever the operator, h values vary from −1.14 to +1.14. But, although h values are in the interval [-2, +2], they do not present any random alternation of the positive and negative values, indicating therefore that none of the analysts (operators) presents a satisfactory situation.

In addition, the figure 3 B presenting Mandel k statistics diagram shows that all values are positive. Some of them are superior to the limit value (+2), notably for analysts 2 and 3. However, no specific tendency can be observed, pointing therefore out the homogeneity of samples under study.

New sampling plan

The purpose of this study is to propose a new sampling plan and to compare it to the existing one. It consists in defining the sample size to draw in order to determine properly the defective nuts proportion. The standard error method was used, supposing that the maximal value of this error admitted in the evaluation of defective proportion is 5%. To determine this proportion p, preliminary tests were made. The mean value of p (p_{mean}) obtained is equal to 0.33 and its maximal value (p_{max}) is 0.55, corresponding respectively to a sample of 354 and 396 nuts. But if p is set to 0.50 as suggested by Kolher (1988), the maximal value of the sample size n is 400 nuts, which corresponds to a sample of about 2 kg. This result is in accordance with the mass approach used for example in cocoa nuts sampling (International Standardization Organization, 1977).

The sampling method proposed, in this study, consists in drawing systematically samples from population (bags) at a precise interval. If we suppose that the population is composed of 375 bags weighting 80 kg each, a normal distribution sampling will be made with a step of 12 (375/30) bags. Therefore, sampling will be made on bags using this step in order to reach about thirty elementary holds. This leads to a

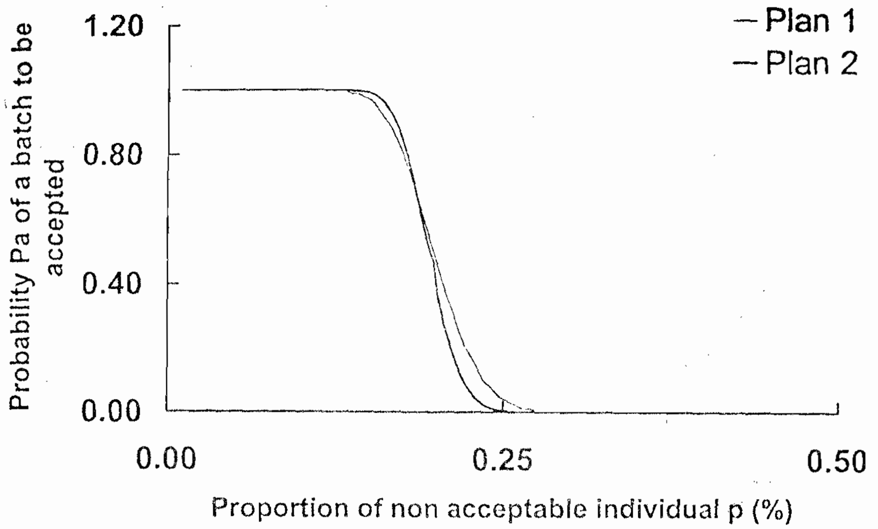

Figure 4: Plans 1 and 2 efficiency curves comparison

total of 36 bags; that is about 9% of bags, to test. This proportion is lower than the one actually used (20%). However, this low proportion, although reducing the technical and analytical precision, does not decrease the sampling precision (Mead *et al.*, 1993). Moreover, the norm NI 01.05.009 (Normalisation Ivoirienne, 1993), relative to the oleaginous seed sampling, requires that the elementary sampling must be done on 2% of the population (bags). Therefore, the proportion commonly used (20%) is extensively far from the fraction that should be tested.

In our method, the nuts obtained after sampling must be mixed, and then divided in quarters, to keep a batch of 400 nuts.

Comparison of sampling plans

The efficiency of both sampling plans is determined and represented in figure 4. Samples sizes (n) are fixed respectively to 200 and 400 nuts for plans 1 and 2. The acceptance criterion (*A*) is the same for both plans, and was set to an outturn of 49, meaning a proportion of defective nuts of about 77 on 400 or 38 to 39 on 200 nuts.

When analysing figure 4, it was observed that efficiency curve of the plan 2 (proposed plan) is more abrupt than the plan 1 (actually plan) one. For the smaller values of *p* (corresponding to batch of good quality), the acceptance probability is higher in the second plan than in first one (plan 1). On the other hand, for *p* higher values (corresponding to batch of bad quality), the acceptance probability is lower in the second plan.

In addition, the producer risk *PR*=5.00% (that is 5% of luck for a supplier to be refused an acceptable quality batch) corresponds to a producer risk quality *PRQ*=15.00% and 16.00% of defective nuts respectively for plan 1 and plan 2. To the client risk *CR*=10.00% (10% of luck to accept a batch that must not be accepted), corresponds to a client risk quality *CRQ*=23.00% and 22.00% of defective nuts for plans 1 and 2, respectively.

When the producer and the client risks are supposed equal (*PR*=*CR*=50.00%), the defective proportion is 19.80% for plan 1, whereas the one of plan 2 is 19.40%, leading respectively to a discriminant ratio of 1.50 and 1.33. It appears therefore that plan 2, which ratio is nearest to 1.00, is more efficient to discriminate good batch from bad one. It better protects the supplier (reducing the risk to be refused a batch of good quality) and the customer (reducing the risk to accept a batch that is of bad quality).

Table 6: Outturn value according to major and significant level

Sample i	Maj-Def (Mi)	Min-Def (mi)	Outturn(yi)
1	0.18	0.12	43.83
2	0.23	0.11	41.99
3	0.33	0.11	36.20
4	0.13	0.09	47.30
5	0.28	0.11	41.11
6	0.21	0.09	41.60
7	0.20	0.10	42.93
8	0.26	0.09	40.50
9	0.22	0.16	39.10
10	0.26	0.16	36.99
11	0.17	0.09	48.90
12	0.21	0.11	41.43
13	0.26	0.13	39.03
14	0.21	0.12	41.68
15	0.21	0.11	43.93

NB:Maj-Def: Major defects; Min-Def: Minor defects

Table 7: Major and minor defects coefficients and their minor defects rates

Model	Coefficients	SD	STUDENT observed value t	**Coefficients significant level**
constant c	59.91	2.10	28.51	**
Maj-Def (Mi)	-51.01	7.53	-6.78	**
Min-Def (mi)	-59.64	16.05	-3.72	**

Table 8: ANOVA study of the present analytical method and the proposed one

Variations source	Sum of squares	Degree of freedom	Variance	F calculated value	F critical value
Sample	3592.59	17.00	211.33	66.27	1.77
Method	3.20	1.00	3.20	1.00	3.97
Interaction	27.12	17.00	1.60	0.50	1.77
Residual	229.60	72.00	3.19		
Total	3852.50	107.00			

After sampling method, what analysis method can we propose to estimate properly the outturn?

Proposition of a new method of outturn determination

In order to appreciate the weight of the usable almond, we propose to determine it using an equation as follows:

$$Y = aM_i + bm_i + c$$

With M_i the major defects (empty, moth-eaten, buttered, mouldy and stunted nuts), m_i the minor defects (stung, immature and partially damaged nuts) and c a constant. According to Prodi *et al.* (1994), *c* value ranges from 52.90 to 62.08. To determine Y, 15 samples were selected and analysed as previously described. The different defects rates are summarised in the table 6.

Linear multiple regression method used enables *a*, *b* and *c* determination as presented in the table 7.

As expected, the coefficients *a* and *b* are negative, indicating that the weight of usable almond is a decreasing function of defects. The constant value (c=59.91) is in the defined range. On the other hand, the standard deviation of each coefficient, in absolute value, is higher than the tabulated Student coefficient (t = 3.05). All coefficients are, therefore, highly significant (p>0.01). Thus, the mathematical model suitable to determine the outturn is:

$$Y = -51.01 \times M_i - 59.64 \times m_i + 59.91$$

Is this new method different from the previous method? In order to check an eventual difference between both studied methods, a double criteria (samples and methods) analysis of variance (ANOVA) was performed using a set of 15 samples. The results obtained are presented in table 8.

It appears (table 8), concerning samples, that the F calculated (66.27) is higher than the F tabulated (1.77). Therefore, the samples studied are different (p>0.05). But, the F calculated (1.00), for methods, is lower than the F tabulated (3.97) indicating that no significant difference (p<0.05) exits between both methods for outturn determination. But the method which is proposed in this study is easier and more accurate.

CONCLUSION

The present work points out the nut characteristics fluctuations. Thus, the diversity of analyzed samples origins confers to these parameters an important dispersion level. Except the stunted nuts, all quality parameters under study differed significantly (p>0.05) from one year to the other. However, the mean quality obtained (47-49) remained superior to the limit value of the outturn (44). On the other hand, this output is depreciated by the mouldy nuts and empty nuts that represent 22.00% of defects and cause 64.34% of nuts damage effects. Based on the relationship existing between parameters, cashew nuts are divided into three groups: defects of physiological order (nuts count, empty and immature nuts), defects of fungal origin (mouldy, stung and partially damaged nuts) and the third class composed of the moth-eaten and buttered nuts.
The method usually used for nut quality determination was shown inefficient. Therefore, a new efficient and easy use method was proposed. This new method uses a sample of 400 nuts instead of 200 nuts in previous method. In addition, only 9% of bags were sampled.

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