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Physical characterization of five Ivorian mango varieties with a view to their contribution to the energy mix of Côte d'Ivoire

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ABSTRACT: The Floridian mango varieties Kent and Palmer, two of the exported varieties also used to produce dried mango, mango juice and jam, and three other varieties locally called: «Tête de chat», «Bouche longue» and «Mademoiselle» and translated in English as «Cat Head», «Long Mouth**»** and «Miss», were selected on the market and used for experiments. The mass of the pit, skin and pulp of each variety was determined by weighing. The operation was carried out on several ripe mangoes of each variety and the mass ratios of the pit and skins were determined. The ratios of a variety are used to predict the potential waste products (pit and skin) that can be produced by that variety. As results, the studied varieties Kent, Palmer, Cat Head, Miss and Long Mouth, have a mass percentage of waste (pit + skin), 5.93%, 14.00%, 22.69%, 14.60% and 18.00%, respectively, with an average value of 15.04%. According to the available data on Ivorian mango production, which, according to the sources, is between 140,000 and 150,000 tonnes or between 180,000 and 200,000 tonnes of mangoes per year, the resulting amount of waste would be between 21,056 and 22,560 or between 27,072 and 30,000 tonnes, respectively. This amount of waste could contribute to Ivory Coast 's energy mix if converted into energy.

KEYWORDS: Mango varieties; Kent; Palmer; Energy mix; Côte d'Ivoire.

1 INTRODUCTION

Côte d'Ivoire is an agricultural country that produces many fruits, including several varieties of mangoes. Its current annual production of mango (*Mangifera Indica L*.) is between 140, 000 tonnes and 150,000 tonnes all combined varieties according to PROMAK AFRIC [1] and the interprofessional association called INTERMANGUE [2]. On the other hand, its annual production is estimated to be between 180,000 and 200,000 tonnes according to the Interprofessional Fund for Agricultural Research and Advice (FIRCA) and the Government Information and Advice Center (CICG) [3]. According to Food and Agriculture Organization of the United Nations (FAO), Ivorian mango production is estimated to be around 180,000 tonnes in 2021 compared to 45,206 tonnes in 2010, i.e. an annual growth of 15% [4]. These different figures illustrate the difficulty of obtaining reliable statistics on Ivorian mango production. Only 10% of the estimated annual production of 32,000 tonnes is exported to Europe and some countries in the sub-region [2], while 40% is lost in the form of waste due to its perishable nature [3]. To mitigate these losses, 39 pre-export fresh mango packaging units and 37 processing units have been set up [2]. Processing units typically produce dried mango, mango juice and jam and produce organic compound waste, mango pits and peels. In order to determine the waste that is produced by mango production and processing units, it is important to assess the mass proportions of the pits, pulp and skins produced by different mango varieties. Such study has not yet been undertaken for several mangoes varieties of Côte d'Ivoire, at least to our knowledge, hence the originality of the present study. To achieve the set goal, the choice fell on two Florida varieties, Kent and Palmer, and three other varieties, 'Cat Head', 'Miss' and 'Long Mouth' which are widely produced and consumed locally. Kent is the most produced, exported and used variety by processing units in Côte d'Ivoire. It

accounts for 80% of all dried mangoes in Côte d'Ivoire [1]. The same variety is used by processing units in Mali [5]. On the other hand, the varieties mainly processed in Burkina Faso, which is one of the major exporters of dried mango in the West African sub-region, are Amélie, Brooks, Kent, Lippens and Springfield. The Amélie variety is the most processed in all processing units in this country [5]. These varieties, which are used in processing units, do not contain fiber and are much sweetened [5]. There are several varieties of mangoes and their presence differs from country to country for various reasons. There are at least 14, 13, 35 and more than 150 varieties in Chad, Senegal, Mali and Haiti respectively [6]; similarly, more than forty varieties have been identified in Burkina Faso [7]. These few examples show the diversity of mango varieties that exist according to geographical space. This diversity could also be explained by the gradual penetration of varieties in different countries according to national or international market demand for products resulting from the processing of this fruit. Indeed, the more a variety is in demand on the world market, the more other countries that do not have it rush to domesticate it in order to reap the resulting financial benefits.

The present work will adopt the following plan. The different percentages of waste skin + pit of each mango variety determined experimentally will be presented. This will be followed by the analysis of these results, which will serve as a basis for the total estimation of waste resulting from mango production in Côte d'Ivoire. Based on these results, the contribution of this waste to Côte d'Ivoire's energy mix will then be evaluated. The originality of this work also results in the fact that this waste is evaluated with a view to contributing to the energy production (thermal or electrical) of Côte d'Ivoire and other African countries, unlike its basic use as livestock feed in most mango-producing countries [8].

2 MATERIALS AND METHODS

2.1 EQUIPMENT

2.1.1 DATA ON MANGOES

Côte d'Ivoire produces between 140,000 and 150,000 tonnes of mangoes each year, of all varieties according to INTERMANGUE [2] and PROMAK AFRIC [1]. It is also the leading producer and exporter of mangoes in West Africa and the 3rd largest supplier to the European market with around 32,000 tonnes [9] or 35,000 tonnes [10] exported in 2022. But according to experts, this quantity will decrease in 2023 due to the vagaries of the weather and will be around 20,000 tonnes [9]. The evolution of the quantity of mango exported from 2010 to 2023 is presented in Table 1 [2]. Quantities delivered to the international market have steadily increased until reaching a peak of 33,100 tonnes in 2016. They then almost stagnated at around 33,000 tonnes before falling in 2020 following the coronavirus pandemic [2].

Table 1. Evolution of the quantity of mangoes exported by Côte d'Ivoire from 2010 to 2021 [2] and from 2022 to 2023

Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022*	2023**
Quantity of mangoes exported	12975	19179	15267	16515	20475	23000	33100	33040	33000	32000	25296	32811	32000	20000

"" [10] et "**" [9]*

2.1.2 CHOICE OF MANGO VARIETIES

In this preliminary study, five varieties of mangoes, two of which are widely exported, "Kent" and "Palmer", and three varieties which are produced and consumed locally and called "Tête de chat"," Bouche longue" and "Mademoiselle" and translated in English as "Cat Head", "Long Mouth**"** and "Miss" in the paper, were used for the experiments. Of course, there is a wide variety of mangoes as explained above, but the choice fell on certain varieties commonly marketed and consumed in Côte d'Ivoire and available in Abidjan at the time of the present study. However, the Amélie varieties (early variety), Keitt and Brooks (late variety) which are also produced, exported and used by processing units in Côte d'Ivoire were not taken into account due to lack of availability on the central market of mangoes in Abidjan at the time of the study. It should be noted that the Kent variety is the most produced, the most exported and also the most used by Ivorian dried mango processing units. In fact, it accounts for 80% of all dried mangoes produced [2]. The prospective study will therefore focus on the Kent variety because data on it are available unlike the other varieties. It is the most appreciated and sought after variety on the market in the countries of the European Union [5] where it is considered the reference for mangoes sold [11]. By comparison, Burkina Faso, a major producer and processor of the varieties used in descending order by the processing units are Amélie, Brooks,

Kent, Lippens and Springfield [12]. To determine the amounts of waste produced from the mangoes, samples of the selected varieties were cut and weighed to assess the mass of skin, pulp and pit contained in each mango variety.

2.1.3 MEASURING APPARATUS

For the determination of the different masses, two scales were used. These are: The Mini Electronic Scale "Professional Digital Table Top Scale" brand: GE070HA1H8XLMNAFAMZ, maximum load: 600g with an accuracy of 0.01g (Figure 1) and the "Denver Instrument" brand S.602 electronic scale; Maximum load: 600g and accuracy: 0.01g (Figure 2).

Fig. 1. Mini multifunction electronic scale "Professional digital table top scale" from GE070HA1H8XLMNAFAMZ with its two trays

Fig. 2. Denver Instrument Electronic Scale

2.2 DETERMINATION OF DIFFERENT MASSES

Each sample of ripe mango was weighed and then cut to separate the skin, pulp and pit. The pit and skin were then cleaned and stripped of the pulp. They were weighed separately and the mass of the pulp was obtained by the difference between the initial mass of the mango and those of the skin and pit. Figure 2 below shows a mango cut into two parts as well as wet waste extracted. The masses of the pits and skins were determined by direct weighing on a scale as shown in Figure 3, while the masses of the pulp were obtained by difference as explained above. The study was carried out with several mango samples of each variety. The percentages of skin, pulp and pit were then calculated in relation to the initial mass of the mango. Statistical averages of these percentages have been reported in Table 2.

Fig. 3. On the left a mango cut into two parts and on the right the removed pit and skin of this mango

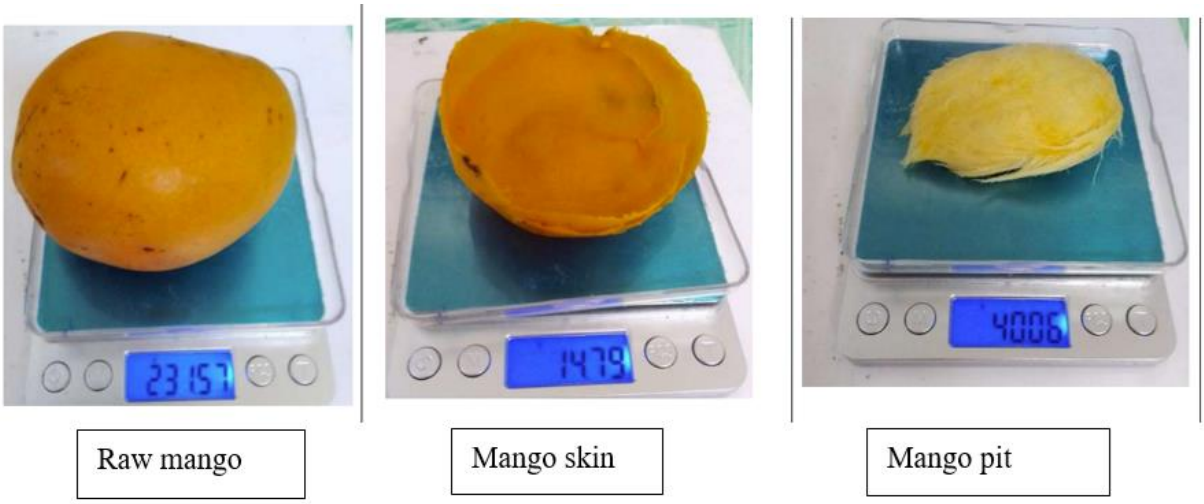

Fig. 4. Experimental determination of the mass, skin and pit of a mango

3 Results And Analyses

3.1 Percentages Of The Different Components Of A Mango For The Varieties Studied

Table 2. Summary of the experimental determination of the different components of the mango varieties studied

	Mango variety name	Gross mass of mangoes used(g)	Average Percentage by Weight of Pulp (%)	Average Mass Percentage of pit (%)	Average Percentage by Weight of skin (%)	Average Percentage by Weight of pit and skin (%)
Florida varieties (for export)	Kent	470.14 -537.71	94.07	02.18	3.75	5.93
	Palmer	248.21 -589.99	85.97	09.57	4.43	14.00
Local varieties (for local consumption)	Tête de chat	140.05 -322.02	77.31	16.23	6.46	22.69
	Mademoiselle	164.38 -245.60	85.50	10.20	4.40	14.60
	Bouche longue	145.50 -196.38	82.10	13.20	4.80	18.00

The analysis of Table 2 shows the following observations. Varieties intended for export (Kent and Palmer) have a higher pulp content (85.97 and 94.07%) than locally consumed varieties with a content of 85.50%; 82.10% and 77.31%, respectively, for varieties Tête de chat, Mademoiselle and Bouche longue. This high pulp content would be an asset for these varieties intended for export. As a result, they have the lowest waste rates skin and pit of 5.93% and 14.00% for Kent and Palmer, respectively. Compared to the three landraces, these two varieties also have the highest gross mango masses. They range from

470.14g to 537.71g for the Kent and between 248.21g and 589.99g for the Palmer; however, these varieties may have higher masses than those encountered in this study. The varieties intended for local consumption, which are Tête de chat, Mademoiselle and Bouche longue, have lower gross masses of mango than those intended for export; they vary between 140.05g and 322.02g, 164.38g and 245.60g and 145.50g and 196.38g, respectively, for the first, second and third varietie. They have lower pulp contents. It is equal to 77.31%, 82.10% and 85.50%, respectively for Tête de chat, Mademoiselle and Bouche longue. Moreover, their pit and skin content are higher than for commercial varieties. On the one hand, it is 16.23%, 13.20% and 10.20%, for the cores and on the other hand, 6.46%, 4.80% and 4.40% for the skin, respectively for Tête de chat, Bouche longue et Mademoiselle varieties. The latter varieties will therefore have a higher mass of waste that will vary between 14.60 and 22.69%. From the above, it appears that these local varieties have less advantage than the processed and exported varieties Kent and Palmer, for which a high pulp content and no fibre and a very low waste rate are sought. It should be noted that the mass percentages of pulp, pit and skins are very similar for the Palmer (14.00%) and Mademoiselle (14.60%) varieties, although they have very different mangoes gross masses between 248.21 and 589.99 g for the former and between 164.38 and 245.60 g for the latter.

3.2 COMPARATIVE ANALYSIS

The determination of the physical characteristics of mangoes has been carried out by some researchers. For example, Kanté-Traoré et al have characterized, for Burkina Faso, 14 species of mangoes that are almost unknown to local processors [7]; while the four best-known varieties: Amélie, Brooks, Kent and Keitt have been characterized by other researchers [13]. Passannet et al [14] did the same for 14 varieties of mangoes from Chad. The varieties common to the three studies in the present work are Palmer and Kent. For a comparative study, the characteristics of these varieties have therefore been summarized in Table 4. For the Kent variety, the gross mass of the mango used for the study varies between 441.14 and 582.57g for mangoes from Chad; those of Côte d'Ivoire are in the same range while those of Burkina Faso have a mass of up to 750g. For the Palmer variety, the Burkinabe mangoes used in their study have a higher mass (between 503 and 790 g) than that of Chad and Côte d'Ivoire. For the percentages of Kent mango pulp, they are between 80.4 and 83.40% for Burkinabe and Chadian mangoes, while the average determined for Ivorian mangoes, which is 94.07%, is higher. Similarly, for the Palmer, the pulp content of the Ivorian mango (average 85.97%) is higher than that of Burkina Faso (between 78.78% and 80.02%) and that of Chad (between 79.22% and 80.38%). It should be noted that during the Ivorian experiments, all the pulp was removed from the skin and the pit to have a skin and a pit entirely devoid of pulp (Figure 4). This approach will result in lower skin and pit percentages in the case of Ivorian fruits compared to those of Burkina Faso and Chad. However, the percentage of the pit of the Ivorian Palmer (09.57%) is higher than that of Chad and lower than that of Burkina Faso (11.71 and 12.33%). The difference between the percentages of pulp, pit and skin could be due to the techniques used to obtain and evaluate them, on the one hand, and to the environmental and climatic conditions in which the plants grow on the other...

Table 3. Comparison of Mango Variety Characteristics: Kent and Palmer

Varieties	Gross Mass Used (g)	Pulps average %MS(%)	Pits average %MS(%)	Skins average %MS(%)	Origin	Reference
Kent	470.14 – 537.71	94.07	02.18	3.75	Ivory Coast	The present work
Palmer	248.21 -589.99	85.97	09.57	4.43		
Kent	441.27 – 582.57	81.21 – 83.40	5.94 – 7.08	10.79 – 11.08	Chad	[14]
Palmer	325.48 – 509.86	79.22 – 80.38	7.04 – 8.57	12.34 – 11.95		
Kent	750	80.4	6.2	13.4	Burkina Faso	[13]
Palmer	502.77 – 790.23	78.78 – 80.02	11.71 – 12.33	7.93 – 9.65		[11]

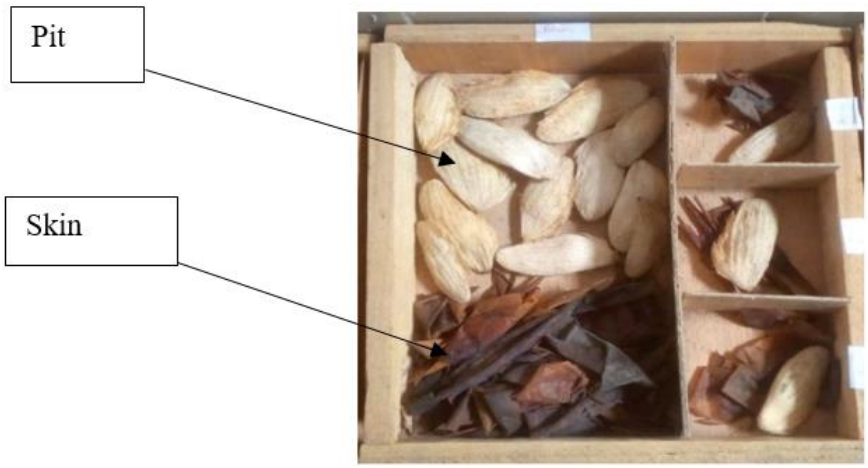

Fig. 5. Pit and skin of the Palmer variety obtained after total extraction of the pulp

3.3 Assessment Of The Amount Of Mango Waste Produced In Côte d'Ivoire And Its Contribution To Its Energy Mix

The local varieties of mangoes are not professionalized and even have a name of wild mangoes or <mango>>. As a result, they are not quantified and therefore data on their production are not available. The varieties most produced for local consumption are Tête de chat, Bouche longue, Miss. But their annual production is not available and is not quantified by the stakeholders. The export varieties "Kent" and "Palmer" are professionalised and estimates for the processing of mango by drying, particularly for the Kent variety, are available. Estimates of waste quantities initially focused on this single mango variety using the data in Table 2. From these results, calculations were made to determine the total quantity of mango produced in Côte d'Ivoire. The annual amount of dried pulp produced by mango drying units from 2017 to 2021 is given in Table 4 below as well as that of fresh mangoes used for this production [1], [2]. As for the amount of fresh Kent mango, it is estimated to be 80% of this total amount of fresh mangoes processed. The mass of wet waste and mango pulp is estimated from the different percentages in Table 2. The various results obtained are summarized in Table 4.

Table 4. Estimated wet waste and pulp (tonnes) of Kent produced by drying units from 2017 to 2021

Years	Amount of fresh mangoes used [2]	Amount of dried pulp obtained	Fresh Kent mango quantity	Fresh Kent pulp quantity	Amount of Kent Kernels Produced	Quantity of Kent pelts produced	Quantity of Kent Waste produced
2017	1239.81	88.558	0991.85	933.03	21.62	37.19	58.81
2018	2428.87	173.491	1943.10	1827.87	42.36	72.87	115.23
2019	2625.04	187.503	2100.03	1975.50	45.78	78.75	124.53
2020	4137.25	295.517	3309.80	3113.53	72.15	124.12	196.27
2021	8300.60	592.900	6640.48	6246.70	144.76	249.01	393.77

The amount of waste (Pit and skin) from the drying of Kent mango by processing units increased from approximately 59 tonnes in 2017 to over 394 tonnes in 2021. It should be noted that the current dried mango production does not cover the entire demand of the international market [2]. This estimate shows that Kent, with the smallest core, can produce waste from 59 to 394 tonnes in five years. This waste production will therefore increase if its production increases because of strong demand on the international market. It should be noted that these estimates do not yet take into account other mango varieties. The latter are expected to increase the total amount of waste resulting from the mango sector.

As data on each mango variety produced in Côte d'Ivoire was not available to refine the calculations and determine the total amount of mango waste in this country, an average of all mango waste values in Table 2 was made. It amounts to 15.04% by weight for the five mango varieties studied. The Ivorian quantity of mangoes produced is between 140,000 and 150,000 tonnes per year according to the inter-professional association called INTERMANGUE [1] and PROMAK AFRIC [2]. With the average waste of 15.04%, the amount of mango waste would be approximately between 21,056 and 22,560 tonnes per year. If data from FIRCA and CICG data [3] are considered, the amount of waste produced is estimated to be between 27,072 and

30,000 tonnes. These quantities represent a first approach to be refined if reliable statistics were available. These quantities of mango waste, if recovered for energy, would increase the share of biomass in Côte d'Ivoire's energy mix.

Based on the studies of Kanté-Traoré et al. [7] and Passannet et al. [14], the average percentage of mango waste in Burkina Faso and Chad was estimated to 25.27% and 21.14% respectively in relation to the initial mass of mangoes. These percentages are higher than those of Côte d'Ivoire which is 15.04% for the reasons explained above. With an annual mango production between 160,000 and 300,000 tonnes [15] and a waste rate of 25.27%, Burkina Faso could inject between 40,432 and 75,810 tonnes of mango waste into its energy mix. According to data from Tridge [16], the average annual production of mangoes in Chad from 2011 to 2022 is about 35,000 tonnes. With a waste rate of 21.14%, this country could use 7,350 tonnes of mango waste in its energy mix.

The present study shows that in all countries where mangoes are produced, the waste (more than 20% on average) that is inherent and incompressible can contribute to their energy mix. This energy recovery will make it possible to combat environmental pollution and consequently climate change, because this waste, if not used as livestock feed or for other purposes, rots in nature.

4 CONCLUSION

This study deals with the identification of wastes resulting from mango production. The mass percentages of pulp, pit and skin were determined experimentally for five local mango varieties: Kent, Palmer, Bouche longue, Mademoiselle and Tête de chat. Since statistics are available only for the Kent variety, the annual projections of mango waste produced in Côte d'Ivoire were first made for this variety alone before being generalized. The amount of waste resulting from its production and processing alone increased from more than 59 to 394 tonnes between 2017 and 2021. With the assumption of a total mango waste production estimated at 15% with an annual mango production of between 140,000 and 150,000 tonnes [1, 2], the annual quantity of mango waste that Côte d'Ivoire could inject into its energy mix would be between 21,056 and 22,560 tonnes or between 27,072 and 30,000 tonnes if this annual production was between 180,000 and 200,000 tonnes [3]. This quantity is likely to be upgraded due to the increase of this fruit production and its demands. This waste could be an important link in Côte d'Ivoire's energy mix. For the time being, they are not recovered in the majority of cases and left in nature; in this way, they contribute to environmental pollution.

The next step of the study will be to determine the calorific value of mango waste and therefore to assess its energy contribution to Ivory Coast's energy mix in terms of electrical or thermal power.

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