

Evaluation of the morphological and physiological characteristics of ripening of 5 avocado accessions from the Daloa markets in Côte d'Ivoire

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ABSTRACT: The avocado tree (*Persea americana* Mill.), belonging to the *Lauraceae* family, is a fruit tree native to Central America, specifically the mountainous regions of Mexico and Guatemala. It is now widely cultivated in tropical and subtropical regions around the world due to the high demand for its fruit, the avocado. This fruit is particularly prized for its nutritional qualities. The rapid or uneven ripening of certain fruits leads to significant economic losses, particularly in the absence of appropriate storage facilities. With this in mind, the present study aims to: (i) Characterize the different avocado accessions sold in the markets of Daloa through the analysis of their morphological characteristics (size, weight, shape, texture, color, etc.), (ii) Study the physiological dynamics of ripening (loss of mass, variation in firmness, etc.) of these accessions, and (iii) Identify accessions with qualities favorable to storage, marketing, and processing. The study was conducted in the municipality of Daloa in Côte d'Ivoire and identified five avocado accessions from the markets of Daloa. After four days of post-harvest storage, the results confirm that certain accessions have significant advantages for post-harvest storage, agri-food processing, and commercial value. Analysis of ripening parameters revealed that accessions with thick skin and slow softening rates are more suitable for storage and transport, while others that ripen earlier can meet immediate consumer demand.

KEYWORDS: avocado, accessions, post-harvest, storage, Côte d'Ivoire.

1 INTRODUCTION

The avocado tree (*Persea americana* Mill.), native to Central America, is one of the most widely cultivated fruit trees in tropical and subtropical areas. This fruit has high nutritional value due to its richness in lipids, vitamins (E, K, B) and antioxidants, which has led to growing demand on international markets (Bergh, 1992). Economically, avocados are an important source of income for many producing countries, including Mexico, the Dominican Republic, Peru, Kenya, and Chile (FAO, 2021). In Côte d'Ivoire, although avocado cultivation is not yet highly industrialized, its local marketing, particularly in urban markets such as those in Daloa, contributes to food security and the economy of small producers. However, the marketing and processing of avocados are limited by significant morphological and physiological variability between the different accessions marketed (Yao, 2020).

Indeed, avocados vary greatly in terms of shape, weight, skin color, flesh texture, and ripening rate (Bost et al., 2013). This variability makes it difficult to standardize post-harvest practices and poses a major challenge for standardizing fruit quality in the markets. In addition, the rapid or uneven ripening of certain fruits leads to significant economic losses, particularly in the absence of appropriate storage facilities. With this in mind, the present study aims to: (i) Characterize the different avocado accessions sold in the markets of Daloa by analyzing their morphological characteristics (size, weight, shape, texture, color, etc.), (ii) Study the physiological dynamics of ripening (loss of mass, variation in firmness, etc.) of these accessions, and (iii) Identify accessions with qualities favorable to storage, marketing, and processing.

2 MATERIALS AND METHODS

2.1 PLANT MATERIAL

The study focused on avocado fruits. To this end, a preliminary study was carried out in the municipality of Daloa in the Republic of Côte d'Ivoire, which led to the selection of five avocado accessions on which the study was based.



Fig. 1. Avocado fruit

2.2 STUDY AREA

This study was conducted in the Haut-Sassandra region, specifically in the city of Daloa, Côte d'Ivoire. The department of Daloa, located in the center-west of the country, between latitudes 6° and 7° North and longitudes 7° and 8° West, covers an area of 5,423 km². The territory extends over a plateau with an altitude of between 200 and 400 meters, punctuated by plains and lowlands. The vegetation consists mainly of dense forest in the south, while the north is dominated by wooded savanna, which is in constant decline due to agricultural activities. The climate is humid tropical transitional, characteristic of this area.

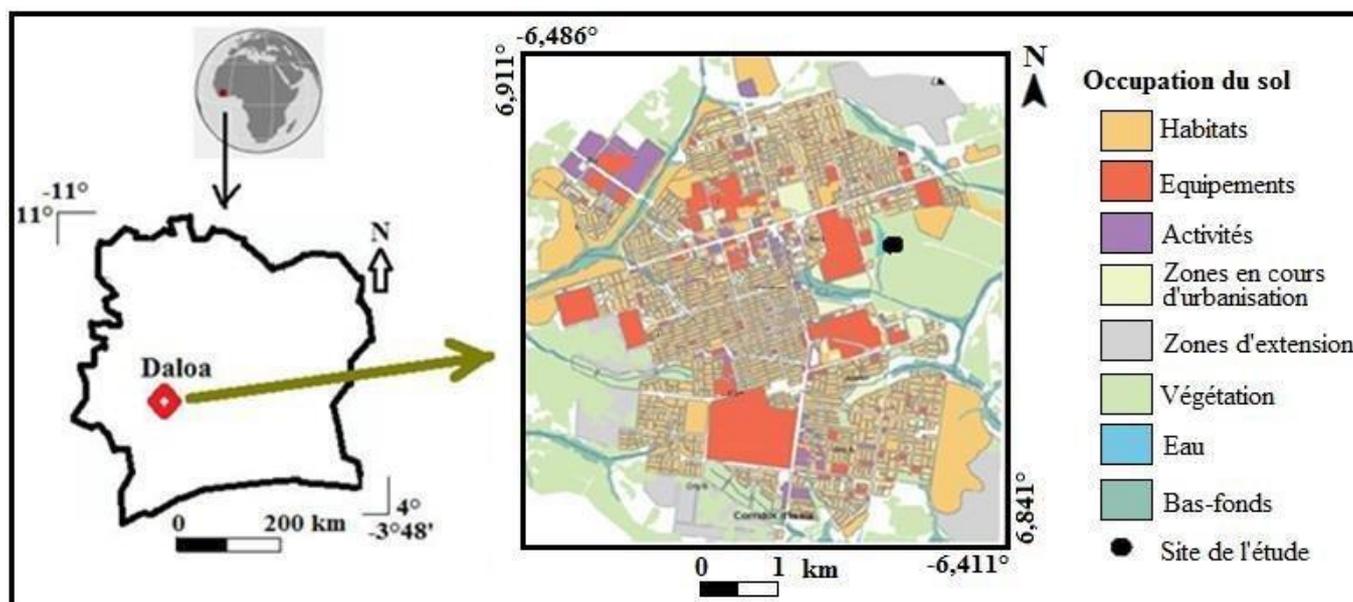


Fig. 2. Map of the city of Daloa

2.3 SELECTION OF AVOCADO ACCESSIONS

The avocados were selected at the markets of Daloa, located in the Haut-Sassandra region of Côte d'Ivoire. The accessions were selected based on their observable morphological diversity (shape, size, skin color) and their presumed origin, as reported by the traders. Each accession comprised a homogeneous batch of fruits, harvested at physiological maturity according to the sellers' indications and confirmed by visual inspection. For each accession, ten fruits were randomly selected from the stalls to ensure the representativeness and reliability of the data collected.

2.4 STORAGE CONDITIONS AND RIPENING MONITORING

After sampling, all the fruit was transferred to a storage room dedicated to ripening. The ambient conditions were carefully controlled to reproduce the typical post-harvest conditions in Côte d'Ivoire. The temperature was maintained between 20 and 25°C, with relative humidity ranging between 60% and 80%, in order to promote gradual and uniform ripening of the samples. Over a period of ten days, daily observations were made to monitor the morphological evolution of the fruit. These observations were intended in particular to document changes in color, the gradual softening of the flesh, and the possible appearance of spots or other signs of deterioration. This phase provided a better understanding of the dynamics of ripening and identified the post-harvest characteristics specific to each accession.

2.5 MEASUREMENT OF FRUIT MASS

The total mass of each fruit, as well as that of the skin, pit, and pulp, was determined using a precision scale, allowing for reliable weighing of the different components. The mass was evaluated daily until the fruit was fully ripe. Average mass and mass variation.

2.6 FRUIT SIZE MEASUREMENT

Fruit size was assessed in three dimensions: length, measured from the apical pole to the basal pole; width, corresponding to the equatorial diameter, using a tape measure; and circumference, using a precision caliper (± 0.1 mm).

2.7 MEASUREMENT OF FRUIT INTERNAL COLOR

External color was observed four (4) days after fruit storage. The fruit was described based on the results observed.

2.8 MEASUREMENT OF FRUIT TEXTURE

Flesh firmness was assessed by penetrating the pulp with a standard two-position penetrometer probe (equatorial and apical). Visual and tactile assessment scale for fruit firmness

Table 1. Fruit firmness evaluation scale

Score	Description of firmness	Tactile interpretation
1	Very firm – Hard fruit, no detectable softness	No collapse under digital pressure
2	Firm – Slightly flexible, but still strong	Very slight deformation under pressure
3	Medium firm – Beginning of noticeable softening	Moderate deformation, fruit still structured
4	Soft – Advanced softening	Strong deformation, flesh visibly softened
5	Very soft – Fruit completely softened or overripe	Almost mushy, very pronounced deformation when touched

(Adapted from Maul et al., 1998; Kader, 2002)

2.9 DATA ANALYSIS

The data collected were organized into Excel tables according to the variables measured. Statistical analysis was performed using R software (version 4.x) or SPSS, according to the following steps: One-way analysis of variance (ANOVA) to detect significant differences between accessions ($p < 0.05$); Post-hoc comparison tests (Tukey HSD) to identify homogeneous groups; Principal component analysis (PCA) to visualize the morpho-physiological structure of the accessions.

3 RESULTATS

3.1 IDENTIFICATION OF AVOCADO ACCESSIONS

Taking into account the morphological diversity of the fruits—their color, shape, and weight—and disregarding their geographical origin. A total of five distinct accessions were identified. These criteria ensured that the local varieties were representative. For each accession selected (Figure 3). These avocado accessions made it possible to understand that the shape of the fruit depended on the pit (Figure 4).



Fig. 3. Identification of lawyer accessions



Fig. 4. Cores of lawyer accessions

3.2 CHANGES IN FRUIT WEIGHT DURING RIPENING

All curves show a slight decrease in weight over time (D1 to D3), reflecting natural water loss. Group 1 maintains a higher weight throughout the period. Group 3 is the lightest (Figure 5). This confirms the trends observed in the first graph.

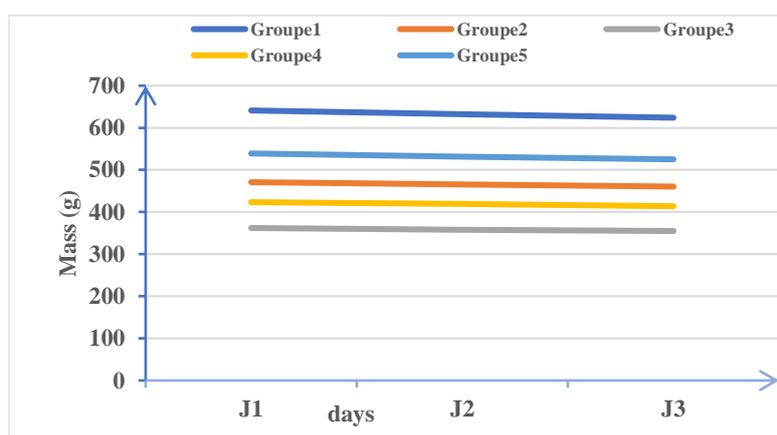


Fig. 5. Mass assessment based on days

3.3 CHANGE IN FRUIT WIDTH DURING RIPENING

Group 5 remains the widest, although its width decreases slightly over time. Group 3 shows the greatest decrease in width, which may be a sign of rapid wilting. The other groups remain relatively stable (Figure 6).

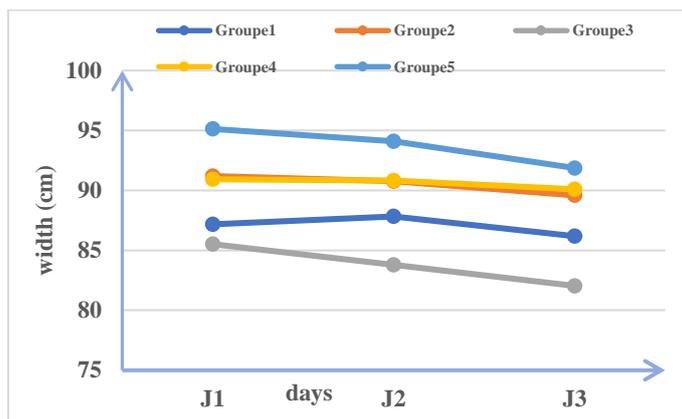


Fig. 6. Evolution of Fruit Width over Time

3.4 CHANGE IN FRUIT LENGTH DURING RIPENING

Length remains very stable over the 3 days for all groups. This confirms that fruit length remains virtually unchanged after harvest, unlike weight or width (Figure 7).

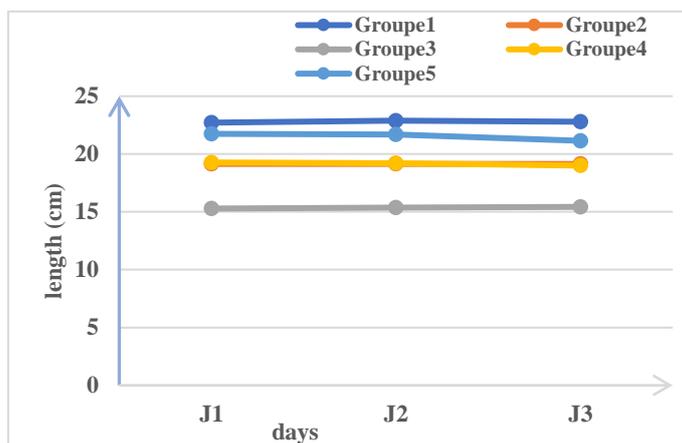


Fig. 7. Evolution of fruit length over time

3.5 CHANGE IN FRUIT CIRCUMFERENCE DURING RIPENING

All groups show a slight decrease in circumference over time, which is consistent with the loss of mass. Group 5 and Group 1 maintain higher values, suggesting better post-harvest performance (Figure 8).

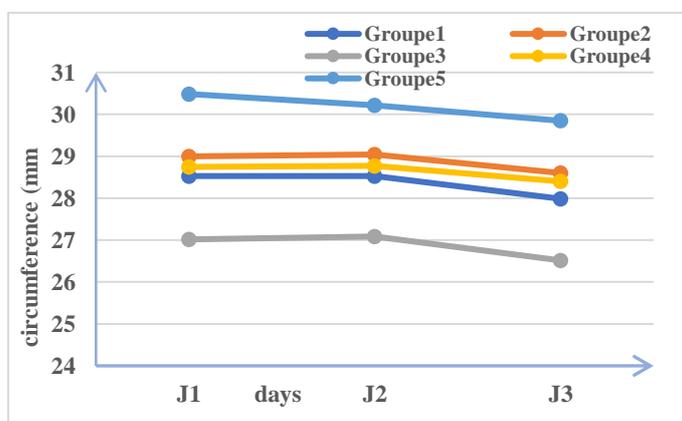


Fig. 8. Changes in fruit circumference over time

3.6 AVERAGE FRUIT MASS AND LOSSES DURING RIPENING

This graph shows that Group 1 has the highest initial mass, followed by Group 5. Group 3 has the lowest mass. Mass losses (in orange) appear low but vary slightly between groups. This reflects water loss or respiration intensity during ripening. Group 1 and Group 2 show the highest mass losses, which may be an indicator of their post-harvest sensitivity (Figure 9).

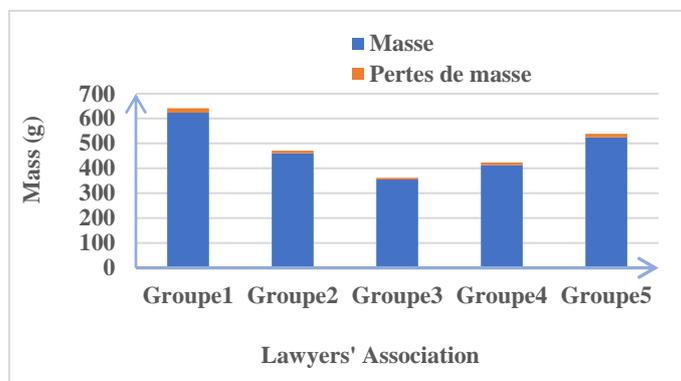


Fig. 9. Average mass of fruit and losses during ripening

3.7 AVERAGE FRUIT WIDTH AND LOSSES DURING RIPENING

Group 5 has the largest width and also the greatest increase in size during ripening. Conversely, Group 1 has the smallest width and very little increase in size. This indicates that some groups (such as Group 5) may continue to change slightly in size after harvest, probably due to residual cellular activity or water absorption (Figure 10).

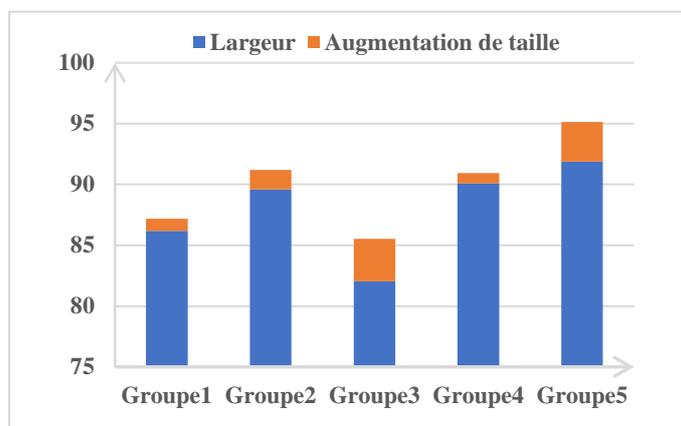


Fig. 10. Average fruit width and losses during ripening

3.8 AVERAGE CIRCUMFERENCE AND FRUIT LOSSES DURING RIPENING

The circumference values are fairly consistent across the groups, with Group 5 and Group 1 leading the way. The variation is very low, suggesting good dimensional stability of the fruit during ripening (Figure 11).

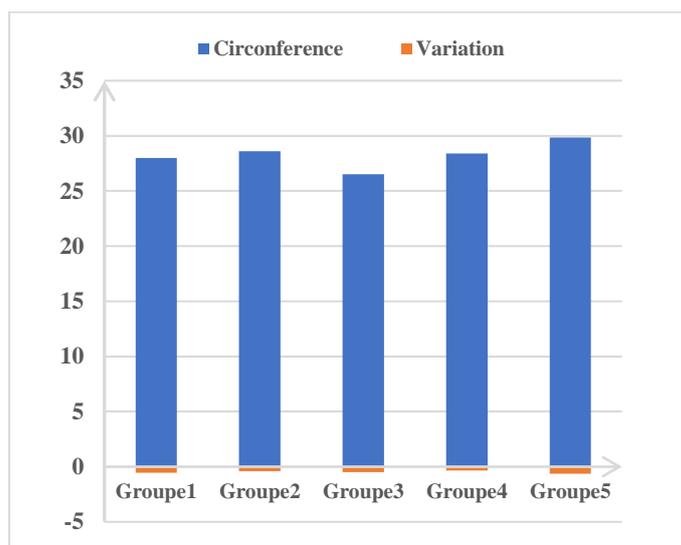


Fig. 11. Average circumference of the fruit and losses during ripening

3.9 AVERAGE FRUIT LENGTH AND LOSSES DURING RIPENING

Lengths varied little between groups, but Group 1 had the longest initial length and a small positive variation. Some groups showed a decrease or stagnation in length, which is normal because length is a characteristic less subject to post-harvest variation than width or circumference (Figure 12).

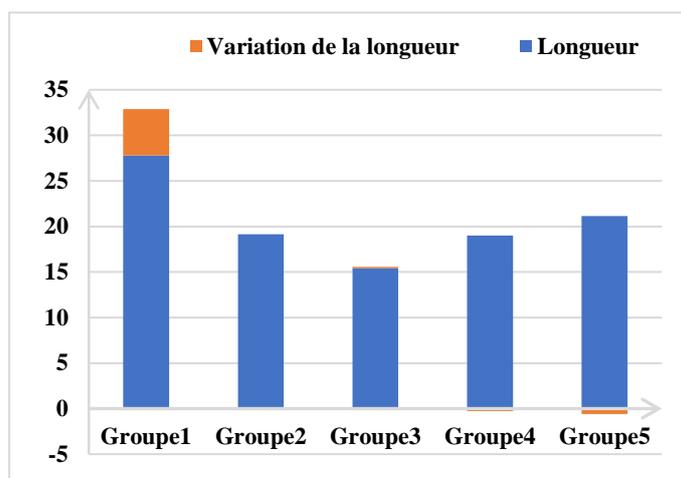


Fig. 12. Average fruit length and losses during ripening

3.10 INTERNAL COLOR MEASUREMENT

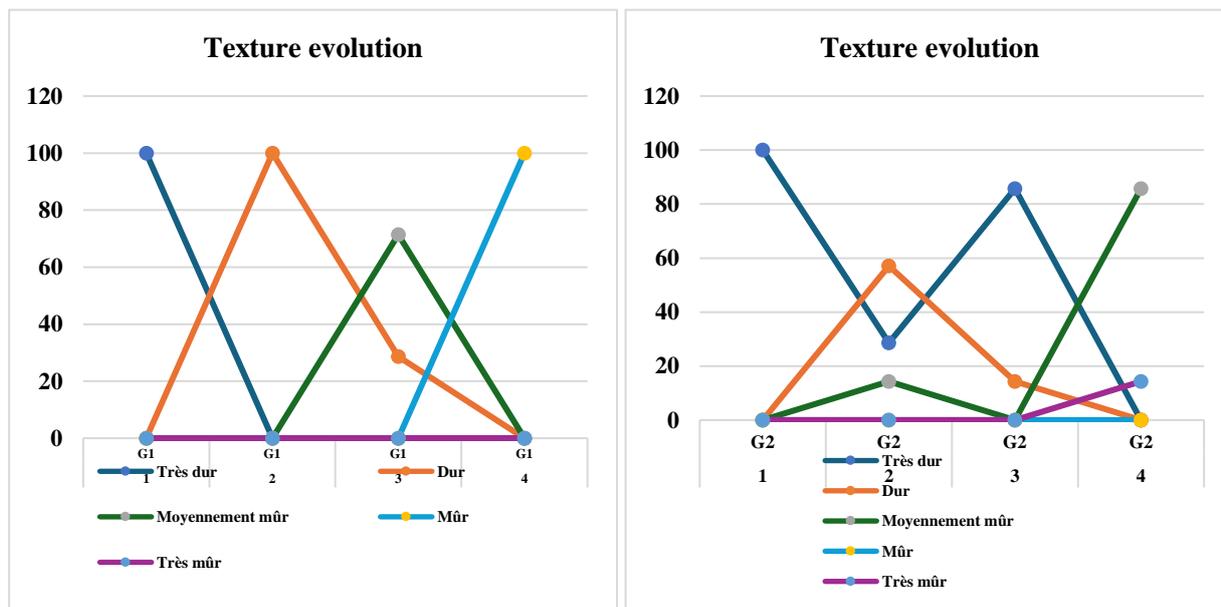
After four (4) days of storage, the external color of the fruit was described based on the observed colors (Figure 11). In Group G1, the avocados showed advanced oxidation, indicating the beginning of rot. Group G2 had fresh avocados with bright green flesh and little browning. Groups G3 and G4 showed slight visible oxidation, with some brown spots on the flesh. Extensive mold and severely spoiled flesh were also observed in the fruit of Group G5, indicating a very advanced stage of decomposition and therefore unfit for consumption (Figure 13).



Fig. 13. Internal color of the fruit after four days of storage

3.11 FIRMNESS

After four days of storage, a notable change in fruit firmness was observed across the experimental groups. Group G1 exhibited a firmness corresponding to 100% very ripe fruit. Groups G2 and G3 showed a similar distribution, with 85% medium-ripe fruit and 15% very ripe fruit. Group G4 maintained a consistent firmness with 100% medium-ripe fruit. Finally, group G5 presented 85% very ripe fruit and 15% ripe fruit (Figure 14).



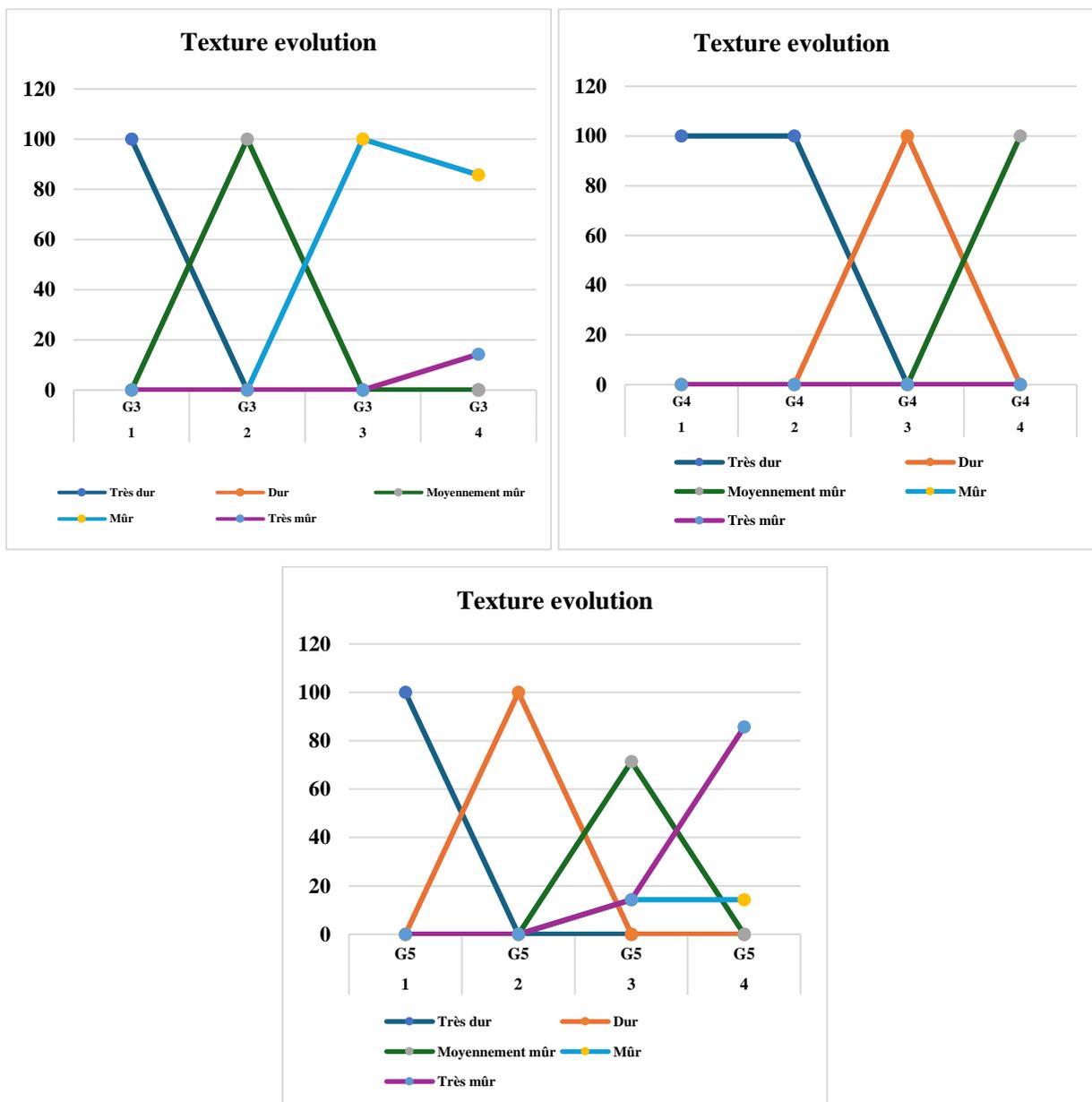


Fig. 14. Evolution of lawyers' firmness over time

4 DISCUSSION

The results of this study revealed significant morphological and physiological variability among the five avocado accessions from the Daloa markets. This observed diversity is consistent with the work of Bost et al. (2013), which highlights that avocado morphological characteristic such as weight, shape, skin color, and flesh texture vary considerably among accessions due to their genetic origin and ecological conditions.

Morphologically, Groups 1 and 5 exhibited the highest weights, which may make them more attractive on the market due to their size (Lecia Rdzak, 2024). Conversely, Group 3, with the lowest weight, could correspond to a less valued local cultivar, but one possibly better adapted to certain specific agroecological conditions (Whiley et al., 2002). Regarding changes in mass and dimensions (width, circumference), a general decrease was observed over the course of several days, reflecting water loss through transpiration and respiration, a well-known phenomenon in climacteric fruits such as avocados (Pesis, 2005). These post-harvest losses are influenced by skin thickness and the cellular structure of the mesocarp (Huyskens-Keil et al., 2006). Fruits from Groups 1 and 2, which experienced the greatest mass losses, appear to be more susceptible to post-harvest deterioration, unlike those from Groups 4 and 5, which exhibited better preservation.

The stability of length during ripening confirms that this trait is relatively unaffected by post-harvest processes, as also shown by Galindo-Tovar et al. (2008). In contrast, variations in width and circumference, although limited, can indicate shriveling or tissue loosening due to flesh softening.

Analysis of firmness revealed that some accessions retain their consistency longer. According to Maul et al. (1998) and Kader (2002), this firmness is a good indicator of maturity and commercial quality. Thus, accessions with lasting firmness (particularly Group 5) are better suited for transport and delayed processing, while those with rapid ripening are suitable for immediate consumption.

Furthermore, the presence of fungal diseases, such as those caused by *Colletotrichum gloeosporioides* or *Botrytis cinerea*, identified in some accessions, poses a major health challenge for the sector. These fungi, often favored by humidity and heat (COLEAD, 2023), are responsible for significant economic losses if they are not properly controlled. This calls for improved post-harvest practices, particularly regarding handling, storage, and packaging.

Finally, this study confirms that the observed fruit diversity is largely due to the lack of rigorous varietal selection in Côte d'Ivoire, as highlighted by (COLEAD, 2023). However, harnessing this genetic variability offers significant potential for implementing breeding programs aimed at meeting the demands of the local and regional markets.

5 CONCLUSION

The study conducted on five avocado accessions marketed in Daloa revealed significant diversity in both the morphological and physiological characteristics of the fruit. This variability, linked to genetic origin and growing conditions, results in notable differences in size, shape, texture, firmness, and ripening rate. The results confirm that certain accessions offer significant advantages for post-harvest storage, food processing, and commercial development. Analysis of ripening parameters revealed that accessions with thick skin and a slow softening rate are better suited for storage and transport, while others, which ripen earlier, can meet the demand for immediate consumption. Furthermore, the identification of fungal infections and physiological disorders during ripening underscores the need for improved phytosanitary management and good post-harvest handling practices. Thus, this study provides a useful scientific basis for guiding varietal selection efforts, improving marketing channels, and developing avocado processing sectors in Côte d'Ivoire. To further explore these results, additional studies incorporating genetic analysis of accessions and performance evaluation under controlled conditions would be necessary.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTES OF AUTHORS

Conceptualization: YKKJ and AKC; Methodology: YKKJ, KNM, and KMC; Data Collection: SBGEM; Drafting - Preparation of the Original Version: YKKJ, KNM, and KMC; Data Analysis and Interpretation: KKD and KKG. All authors have read and approved the published version of the manuscript.

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