

# Morphogenesis of Oil Palm Fruit (*Elaeis guineensis* Jacq.) in Mesocarp and Endocarp Development

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**Abstract:** This work aims to study the development of the pericarp of the fruit of *Elaeis guineensis* Jacq. var. *dura*. The thickness, the water and the oil contents of its tissues are evaluated every two weeks, from pollination to the maturity of the fruit. The development of the oil palm fruit takes 5.5 months. The endocarp reaches its maximum thickness at the 70th DPP (day post-pollination), with a water content of 72%. It then starts its dehydration, while sclerifying. It therefore isolates the seed at start and later protects it. The mesocarp is visible at anthesis and its water content is close to 92%. From the 100th DPP, it begins a continuous dehydration associated, from the 130th DPP, with an active lipids biosynthesis. Ultimately, the pericarp of the oil palm fruit fulfills both functions, namely to protect the seed by early sclerification of the endocarp and ensure the dissemination of the species by the high oil content of the mesocarp. A comparative anatomy of the pericarp tissues of the three genotypes of *E. guineensis* Jacq., during the first three weeks of fruit development, will enhance the understanding of the primary effect of *sh* gene.

**Key words:** *Elaeis guineensis* Jacq., fruit, endocarp, mesocarp, development.

## 1. Introduction

In oil palm (*Elaeis guineensis* Jacq.), the wild material called *dura*, of genotype  $sh^+sh^+$ , carries fruits with a thick endocarp and a thin mesocarp. This material yields about 0.5 tons of palm oil per hectare [1]. Earlier on, a mutation of this material appeared on the *sh* locus controlling the inheritance of the thickness of the endocarp in oil palm. In the homozygous state, this mutation leads to fruits without endocarp and abundant mesocarp. This homozygous genotype,  $sh^-sh^-$ , is called *pisifera*. Unfortunately, such trees tend to produce little or no bunch at all [2, 3]. In the middle of the 20th century, it was shown that the crossing between *dura* and *pisifera* genotypes leads to a palm tree with thin-shelled fruits and a relatively thick mesocarp [4,

5]. This hybrid of genotype  $sh^+sh^-$  is called *tenera*. It is considered as the improved variety of oil palm and is systematically used in all the industrial palm groves and the majority of smallholders' groves [6-9].

Reducing the endocarp, in turn enriching the fruit mesocarp, thus appears to be the major criterion in improving oil palm. One of the future stakes in this domain is to develop *pisifera* genotypes with an optimal female fertility. To achieve this goal, it is important to understand the absence of endocarp is associated with a female sterility in the genotype *pisifera* of today. On the genetic level, it is to understand the impact of *sh* gene on the female fertility and therefore on the development of fruit.

In this context, the general objective of the present study is to describe the development of different tissues of the pericarp of the fruit of *E. guineensis* Jacq. var. *dura*, from which the three tissues of this

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part of the fruit (exocarp, mesocarp and endocarp) are set up. The specific objectives are to monitor the implementation and the evolution of the endocarp and the mesocarp in this variety of oil palm.

## 2. Materials and Methods

The plant material is gracefully obtained from the Specialized Oil Palm Research Centre (CEREPAH) of La Dibamba (Cameroon), a station of the Institute of Agricultural Research for Development (IRAD). It is composed of fruits taken off from bunches of palm trees in the course of maturation.

Five assisted pollinations are made between *dura* (female parent) and *pisifera* genitors (Table 1). The samples are made of fruits taken from bunches, every two weeks from the first DPP (day post-pollination) to the maturity of bunches. Maturity is evidenced by the natural detachment of the first fruits. At each stage of the study, 30 fruits were collected from the whole bunch, that is, 150 fruits for the five bunches.

Cross or longitudinal sections of the fruits collected were made and observed with the naked eyes and/or by means of an optical microscope EUROMAX provided with a micrometer. These observations aim essentially at determining the deadline of appearance (onset) of pericarp tissues (mesocarp and endocarp). The various measurements taken on these tissues allow taking note of the following changes from pollination to the fruit maturity:

- the thickness of the mesocarp, mainly assessed

**Table 1** Genitors used and controlled pollinations made at CEREPAH.

Date of pollination	Matings		
	♀ Genitors		♂ Genitors
09/26/2011	A98D 22 14	×	LD2272 P
	A98D 23 21	×	LD2272 P
	B91D 29 07	×	LD1568 P
	C19D 14 08	×	LD2272 P
	C19D 24 17	×	LD2272 P

D: *E. guineensis* Jacq. var. *dura*; P: *E. guineensis* Jacq. var. *pisifera*.

using a graduated ruler;

- the thickness of the endocarp, measured microscopically for early stages of fruit development (0-56 DPP). In later stages, this parameter is estimated

by the formula  $E = \frac{\phi_m(nut) - \phi_m(seed)}{2}$ , with  $E$ , the

endocarp thickness and  $\phi_m$ , average diameter [10];

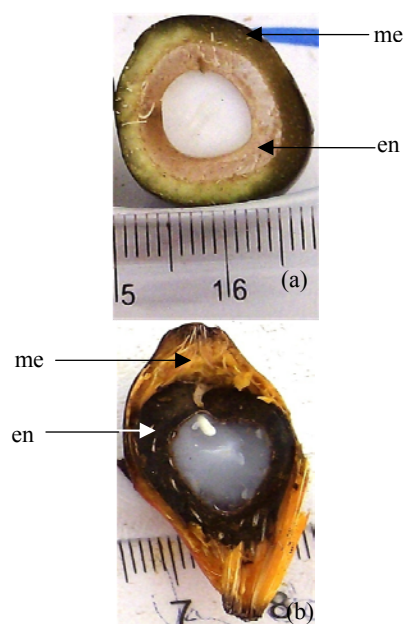
- the water content of both fruit tissues, estimated by a method described previously [11, 12];
- the oil content of the mesocarp, evaluated from the total lipid extracted by Soxhlet method [13, 14].

For every stage, the averages and standard deviations of the various parameters are calculated. Curves presenting the evolution of these parameters over time are produced using the Microsoft Excel 2007 software.

## 3. Results and Analysis

### 3.1 Maturity of Fruits

The first fruits come off the bunch after 165 DPP. This shows that the fruit of the oil palm develops in a complete way within six months. Fig. 1 represents sections of this fruit, in two stages of its development.



**Fig. 1** Sections of fruit of *E. guineensis* Jacq. var. *dura* at a (84) and b (168) DPP. me: mesocarp, en: endocarp.

### 3.2 Endocarp

The endocarp is not noticeable on the day of pollination, but it is visible from the 17th DPP. By that time, its average thickness and average water content are  $0.79 \text{ mm} \pm 0.13 \text{ mm}$  and  $71.99\% \pm 4.76\%$ , respectively. In the 70th DPP, these two parameters have average values of  $2.90 \text{ mm} \pm 0.09 \text{ mm}$  for the thickness and  $62.39\% \pm 5.15\%$  for the moisture content. It is also at the 70th DPP that the germination pores appear in a clear way, at the level of the endocarp (Fig. 2). From the 70th DPP, the average water content of this tissue begins a drastic drop to a value of  $21.85\% \pm 3.44\%$  at fruit maturity. The average thickness of this tissue at the 168th DPP is  $3.02 \text{ mm} \pm 0.16 \text{ mm}$ . Fig. 3 shows the evolution of the thickness and water content of the endocarp during fruit development.

### 3.3 Mesocarp

The mesocarp is visible in the day of pollination. Its thickness is then  $1.55 \text{ mm} \pm 0.21 \text{ mm}$ . It then doubles in two months to reach  $3.23 \text{ mm} \pm 0.19 \text{ mm}$  on the 70th DPP. Afterward its variation becomes lower. It gets to  $4.00 \text{ mm} \pm 0.11 \text{ mm}$  three months later, at fruit maturity.

The first few days after pollination, the water content of the mesocarp has a value between 80% and 90%. At this stage, there is almost no fat in this tissue. The water content will remain maximal until the 100th DPP. After this period, it starts falling, from 92% to 45% in almost 60 days.

As for lipids, their content evolves in an opposing way to the water content in this tissue. Indeed, until

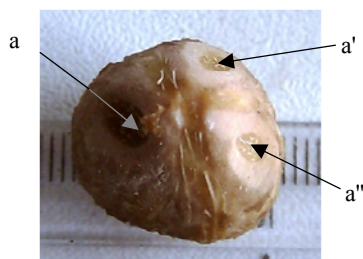


Fig. 2 Nut of *E. guineensis* Jacq. var. *dura* at DPP. a, a' and a'': germination pores.

the 84th DPP, the fat content of the mesocarp is less than 5%. Thereafter, it increases slowly until the 126th DPP, to reach an average of 19.39%. But from this date until maturity of the fruit, the accumulation of lipids in this tissue becomes exponential. This parameter will rise from 20% to 78% in 30 days. Fig. 4 shows the evolution of the thickness of the mesocarp of the fruit of oil palm, as well as that of its water and oil contents.

The study shows that after pollination, the fast growth of the endocarp is the most remarkable phenomenon which occurs at the level of the tissues of the pericarp. This tissue reaches its maximal thickness in 70 days. Afterward, it dehydrates and sclerifies, it establishes a more or less tight barrier between an inner part that constitutes the seed and an outer part

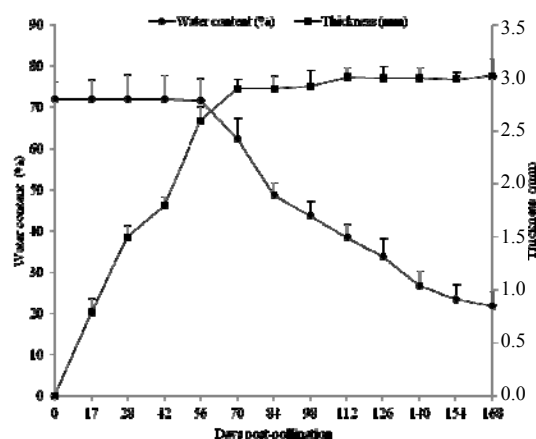


Fig. 3 Characteristics of endocarp during *E. guineensis* Jacq. var. *dura* fruit ripening.

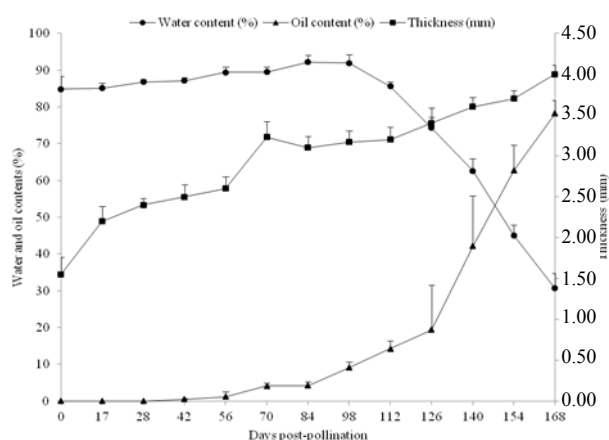


Fig. 4 Characteristics of mesocarp during *E. guineensis* Jacq. var. *dura* fruit ripening.

(the mesocarp). The 70th DPP thus appears as a remarkable date in the evolution of this border-organ within oil palm fruit.

As for the mesocarp, its growth in thickness is sprayed over time and lasts until the 100th DPP. It is also in this period (100th DPP) that the dehydration of this tissue begins. Concomitantly, the oil content becomes gradually significant in this tissue. But it is from the 130th DPP that lipids biosynthesis becomes truly dynamic, until the maturity of the fruit. The 100th and 130th DPP thus appear as notable dates in the development of the mesocarp.

Four major phases can thus be identified in the development of the pericarp of the fruit of *E. guineensis* Jacq. var. *dura*. From pollination to the 70th DPP, the mesocarp is highly hydrated, as well as the endocarp. A circulation of water and dissolved nutrients is possible from the outside towards the hollow center of the fruit. From the 70th to the 100th DPP, the endocarp begins its sclerification, while the mesocarp is still strongly hydrated. This may suggest that at this stage, the transfer of materials towards the center of the fruit slows down and probably becomes more selective. From the 100th DPP, the endocarp intensifies its sclerification and isolates the mesocarp from the inner part of the fruit more and more. At the 130th DPP, the mesocarp can also begin the final phase of its development which is active oil accumulation.

#### 4. Discussion

The pericarp of various fruits, including that of drupe fruits, is typically designed to perform two functions. It serves partly for the protection of the seed and the dispersal of the species [15, 16]. This study indicates that the endocarp of the oil palm fruit, invisible at anthesis, grows very quickly in the first WPP (weeks post-pollination).

Within 10 weeks, the endocarp reaches its maximum thickness, which is not the case for the mesocarp whose maximum thickness is practically

reached at fruit maturity. This early development of the endocarp is also observed in *Olea europae*. For the latter, 90% of the development of endocarp occurs by 8th WPP, whereas 74% of mesocarp's final size is accomplished between the 8th and the 22nd WPP [17, 18].

Similarly, the dehydration of the endocarp (from the 10th WPP) precedes that of the mesocarp (from the 14th WPP) in the oil palm fruit, just as in other drupes such as *Rhus aromatica* and *R. glabra* [19]. The phase in dehydration process of endocarp of *E. guineensis* Jacq. var. *dura* accompanies a hardening, qualified as sclerification in olive [17]. By this early evolution, the endocarp isolates and so protects the seed from the rest of the fruit.

From the 14th WPP, the mesocarp, now isolated from the seed, starts its dehydration, followed by an active lipid biosynthesis from the 18th WPP. Lipogenesis and dehydration observed during the ripening of the mesocarp appear as a rule, not only in the fruit of oil palm [20, 21], but also in that of the olive tree [22-24]. However, in this latter species (*Olea europae*), as in other species with fleshy fruit such as the avocado tree and the African pear tree, the fat content of the mesocarp rarely reaches 40% [25].

It should be noted that in species such as *Mangifera indica* or *Prunus persica*, mature mesocarp remains highly hydrated (more than 80%) and lipids are in trace amounts (< 0.5%), carbohydrates being the majority [26, 27]. Moreover, in other drupes as that of *Cocos nucifera*, mesocarp dehydration leads to the highly fibrous nut, without accumulation of lipids [28, 29]. This evolution makes the mesocarp of the oil palm fruit very attractive to animal species such as *Xerus erythropus* and even humans and so ensures an active dissemination of the species.

#### 5. Conclusion

The pericarp of the fruit of wild oil palm appears as a model in drupes. At a very early stage, the evolution of its endocarp provides isolation and protection of the

seed, while the later development of its mesocarp guarantees its effective dissemination. Further comparative anatomical studies of the endocarp within the first two or three weeks of development of fruits of the three genotypes of *E. guineensis*, as far as the *sh* locus is concerned, are needed. These would help to understand the mechanism of growth in thickness of this tissue and to specify the primary action of the *sh* gene on its development.

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