Physical and chemical properties of *dura* and *pisifera* genotypes of oil palm seed and its viability and vigor

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**Abstract.** Information about seed physical and chemical properties and their influence on seed dormancy, viability and vigor are barely established. The information can be useful to avoid seed deterioration and to maximize germination. This research aimed to observe the physical and chemical oil palm seed properties, and their relation to the viability and vigor. Three genotypes [Ts, Da, and Ce] from the *Dura* variety and one genotype [Gh] from the *Pisifera* variety were evaluated in a completely randomized block design with three replicates. Each genotype had different physical and chemical properties. Seeds of each genotype showed increasing amounts of carbohydrate and decreasing of water, protein, lipid, and lignin content after being held at 40°C for 45 days to break seed dormancy. Genotype Da had the highest viability and vigor compared to Ts and Ce. At the same time, there was no seed of genotype Gh germinate, probably due to the heat treatment was not suitable in breaking dormancy. There were correlations between seed weight, lipid, carbohydrate and lignin properties with seed viability and vigor. Seed protein content seems contributed less to germination compared to seed carbohydrate and lipid content.

1. **Introduction**
*Elaeis guineensis* Jacq. produces the highest edible oil yielding compared to other oil yielding crops. The productivity of oil [palm oil and kernel palm oil] from oil palm accounted for 4.21 t/ha/year is higher than that of oil from annual oil crops in 2012/2013. The productivity of oil from soya bean, the leading oil producer from annual oil crops in a similar year accounted for 2.38 t/ha/year [1].

Oil palm is the leading estate crop commodity in Indonesia. Indonesia becomes the largest producer of palm oil and also the largest consumer in the world. Based on data from [2], the area of oil palm planting keeps expanding for the last five years as much as 2.77-10.55% per year. The total area of oil palm planting was 12.38 million ha in 2017 and estimated increased into 12.76 million ha in 2018, with the total amount of crude palm oil [CPO] produced is about 34.94 million tons in 2017 and estimated increased into 36.59 million tons in 2018.

There are three fruit forms or varieties of oil palm seed, *i.e.* *dura*, *pisifera*, and tenera. *Dura* is used as the female plant, while *pisifera* used as the male plant in producing tenera seeds for cultivation. Thus tenera is the product of the cross of *dura* and *pisifera*. Some specific characteristics of both varieties will influence the characters of their progenies. It means that information of the characters from the parental genotype may predict the characters resulted from the crosses.

Seed germination is a complex chain of biochemical, physiology, and morphology changes. Bareke [3] stated that germination consists of three stages. The first stage is imbibition and metabolism activation. The second stage is digestion of seed storage reserved in cotyledon or endosperm and...
translocation of sugar to an embryo, and the third stage was cell division and growth initiation. Seed coat breaking and finally, seedling emergence designates a morphological germination observed after physiological germination. Genetic or intrinsic seed and environmental factors determine the success of seed germination [4]. The genetic factors that influence the process are chemical compounds, enzymes, and the physical and chemical properties of the seed.

Information about seed physical and chemical properties becomes a prerequisite to minimize seed deterioration and maximize seed germination. Currently, the information about whether seed physical and chemical properties influence seed viability and vigor is still lack, especially on oil palm seed used as parent material for producing hybrid Tenera seed. Oil palm seeds have a low germination rate under natural conditions. They can take several years to germinate [5] [6]. Based on Rees [7], Hussey [8], and Corley and Tinker [1] concluded that heat-treatment with a temperature of 37-40°C for up to 80 days is the critical requirement to break dormancy. This research aimed to observe the physical and chemical oil palm seed properties, and their relation to the viability and vigor.

2. Material and Methods
The experiment was conducted in the Laboratory of Seed Technology at Andalas University. A completely randomized block design was used in this experiment with three different fruit bunch as replicates. Seeds from three genotypes [Ts, Da, and Ce] from the Dura variety and one genotype [Gh] from the Pisifera variety derived from seed producer company. Seeds were evaluated for physical and chemical characteristics, and viability and vigor. Seed physical properties observed were seed length, seed diameter and seed weight [9]. The chemical seed properties, i.e. protein, lipid, and carbohydrate amount were estimated based on AOAC procedures [10], while lignin was determined based on TAPPI T222 om-98 procedure [11]. Those characters were observed twice; before and after seed dormancy-breaking. Heat-treatment at 40°C for 45 days was conducted based on the standard procedure used by the oil palm seed producer company to break dormancy [12]. The number of seeds used for each replication for physical measurement was three seeds, while that for chemical measurement was destruction from three seeds. The seed used as a sample was randomly selected.

The germination test consisted of viability and vigor test was conducted after seed dormancy breaking. Selected seeds were soaked for ten days, then dried and placed in tightly tied polyethylene plastic bags. Neon lamp at 35 watts lighted the germination room, while the temperature was maintained around 33°C until 45 days as suggested by [12]. The inspection was conducted every five days by a fine spray. After radicle and plumule emerged, the seedlings were then separated based on the seedling's performance criteria. Measurement of viability and vigor was conducted by several tests, i.e. maximum potential growth, standard germination, first count, and index value tests. The number of seeds used for each replicate was twenty seeds. Data were analyzed using ANOVA, and their mean differences proceeded with Duncan’s test at P<0.05.

3. Result and Discussion
3.1. Physical and chemical properties of oil palm seed
Analysis of variance showed that the fruit bunch did not affect seed physical and chemical characteristics both before and after seed dormancy-breaking treatment. The genotype of oil palm seed showed significant differences in seed physical and chemical properties both before and after seed dormancy-breaking treatment [Table 1]. The ranking of genotypes on each physical characteristic tended to be similar both before and after the heat treatment as a seed dormancy-breaking method. A seed length, seed diameter and seed weight reduced due to the heat treatment.

Seed physical properties had discernible seed characteristics among genotypes. Oil palm seed genotype Gh had a small oval shape [Fig 1a] with a seed length of 1.34 cm and a diameter of 0.91 cm. The average weight of Gh seeds is 0.27 g. The physical characteristics of genotype Gh seed which grouped as Pisifera variety were the smallest among genotypes. After seed-heating at 40°C for 45 days as a dormancy-breaking technique, the physical properties of Gh seed reduced by 29.2, 10.7 and
60.2%, respectively for the length, diameter and weight of seed. Based on the t-test analysis [data was not shown], seed dormancy-breaking by heat method created a significant effect on seed weight for genotype Gs. Genotype Ts seed was a smooth-oval shape with light brown color [Fig. 1b], while genotype Ce and Da seed had an oval shape which sharpens on its tip with greyish-brown color and coarse texture [Fig. 1c and 1d]. Similar to genotype Gh, the length, diameter, and weight of dura genotype seeds decreased [13.0, 17.7 and 7.3%, respectively].

Table 1. Physical properties of oil palm seed of genotypes Gh, Ts, Ce, and Da before and after seed dormancy-breaking treatment

| Genotype | Physical properties |
|----------|---------------------|
|          | PB                  | DB                  | BB                  |
|----------|---------------------|---------------------|---------------------|
|          | Before seed dormancy-breaking treatment |                      |                      |
| Gh       | 1.34 ± 0.28 c       | 0.91 ± 0.29 d       | 0.27 ± 0.16 d       |
| Ts       | 3.14 ± 0.13 a       | 2.13 ± 0.22 b       | 5.61 ± 0.76 a       |
| Ce       | 2.35 ± 0.32 b       | 1.86 ± 0.28 c       | 3.01 ± 0.40 c       |
| Da       | 2.53 ± 0.28 b       | 2.41 ± 0.21 a       | 4.69 ± 1.09 b       |
| CV [%]   | 10.97               | 14.12               | 20.42               |
|----------|---------------------|---------------------|---------------------|
|          | After seed dormancy-breaking treatment |                      |                      |
| Gh       | 0.95 ± 0.03 c       | 0.82 ± 0.78 b       | 0.11 ± 0.07 d       |
| Ts       | 2.70 ± 0.18 a       | 1.86 ± 0.14 a       | 5.15 ± 0.42 a       |
| Ce       | 2.06 ± 0.16 b       | 1.55 ± 0.17 a       | 2.89 ± 0.41 c       |
| Da       | 2.21 ± 0.11 b       | 1.85 ± 0.27 a       | 4.22 ± 0.57 b       |
| CV [%]   | 24.19               | 28.51               | 13.56               |

Means followed by the same letter in a column are not significantly different by the DMRT at P≥0.05. PB: Seed Length [cm]; DB: Seed Diameter [cm]; BB: Seed Weight [g]; CV: Coefficient of Variation

Heat method did not affect a seed weight of a variety of Dura or genotype Ts, Ce, and Da. The difference of measurement on physical seed properties before and after seed breaking-dormancy was in line with a reduction of seed water content due to a heat-treatment as presented in Table 2.

Oil palm seed genotype Gh contained high enough amount of water, around 39.52%, becomes the highest and also to be the highest in a reduction of water content [51.5%] due to a heat-treatment. The small size and lack of shells of seed play a role in the high reduction of water from seed. Other than the chemical substances on all plant systems, the seed contains more materials as nutrition storage to support the early process of germination. Generally, chemical substances in seeds are carbohydrates, lipids, oils, ash, and proteins.
Table 2. Chemical properties of oil palm seed genotypes Gh, Ts, Ce, and Da before and after dormancy-breaking treatment

| Genotype | Before Seed Dormancy-Breaking Treatment [%] | After Seed Dormancy-Breaking Treatment [%] |
|----------|--------------------------------------------|-------------------------------------------|
|          | KA  | KP   | KL  | KK  | KG  | KA  | KP   | KL  | KK  | KG  |
| Gh       | 39.5±6.7 a | 0.06±0.01 b | 18.0±0.56 b | 36.2±6.7d | 68.4±0.32 b |
| Ts       | 23.2±1.3 b | 0.12±0.02 a | 7.6±0.66 d | 67.7±1.4a | 65.2±0.40 c |
| Ce       | 18.5±0.7 c | 0.12±0.01 a | 24.2±0.72 a | 54.3±1.0c | 65.1±0.09 c |
| Da       | 18.2±0.8 c | 0.12±0.01 a | 17.0±0.33 c | 61.8±1.0b | 75.0±0.03 a |
| CV [%]   | 14.38 | 13.02 | 3.57 | 6.58 | 0.38 |

| Genotype | After Seed Dormancy-Breaking Treatment [%] |
|----------|------------------------------------------|
|          | KA  | KP   | KL  | KK  | KG  |
| Gh       | 19.2±0.2 a | 0.10±0.01 a | 17.1±0.23 a | 58.5±0.3d | 68.7±0.02 a |
| Ts       | 16.5±1.9 b | 0.06±0.02 c | 3.0±0.02 d | 77.9±1.9a | 62.6±0.01 d |
| Ce       | 12.8±1.2 c | 0.07±0.01 b | 8.3±0.04 c | 76.1±1.1b | 63.0±0.01 c |
| Da       | 11.4±0.9 d | 0.05±0.01 c | 10.7±0.02 b | 74.3±0.9c | 64.2±0.00 b |
| CV [%]   | 8.5  | 20.06 | 1.18 | 1.79 | 0.02 |

Means followed by the same letter in a column are not significantly different by the DMRT at P≥0.05. KA: Seed Water Amount; KP: Seed Protein Amount; KL: Seed Lipid Amount; KK: Seed Carbohydrate Amount; KG: Seed Lignin Amount; CV: Coefficient of Variation.

Genotype Gh was the lowest in the amount of protein [0.06%] and carbohydrate [36.16%] before seed dormancy-breaking treatment. All chemical seed properties of genotype Gh changed to be the highest after seed dormancy-breaking, except the carbohydrate content. Even though the carbohydrate amount of Gh genotype seed was the lowest among genotypes after seed dormancy-breaking treatment, the increase of carbohydrate was the highest [22.32%]. The increase of protein content after seed dormancy-breaking for the Gh genotype was contrary to the decrease of protein content for dura genotypes. The mechanism has not yet understood; however, the genetic characteristic of the genotype may bring on this phenomenon.

The Gh genotype was the *pisifera* variety, used as the male parent in producing tenera hybrid seed commercially. Heat-treatment at 40°C failed to induce the germination process as shown in Table 3. The failure of germination indicates that the dormancy may still exist on the Gh genotype. *Pisifera* seed exhibit a long period of dormancy and more difficult to germinate than *dura* or *tenera* seeds [6] [13] [14].

A seed-heating at 40°C for 45 days as a dormancy-breaking technique consistently dropped the amount of seed water, protein, lipid, and lignin, while that raised carbohydrate content of all *Dura* genotypes. The reduction was a range from 29 to 37% for water content, 41 to 58% for protein, 37 to 66% for lipid, and 3 to 14% for lignin. The increase of carbohydrate content varied among the *dura* genotypes, ranging from 15 to 40%.

Seed water moisture is not prerequisite to break dormancy; however, the moisture content is critical for oil palm germination [7]. The resumption of metabolic activity, i.e. respiratory and protein synthesis activity, progresses rapidly in the first phase of water uptake by seed. Rapid initial uptake of water occurs in this phase, followed by the second phase, which was a plateau in water uptake. Dormant seeds can not enter the third phase; thus they do not complete germination [15].

Proteins, lipids, and carbohydrates existed in endosperm and embryo. Lipids and proteins in seeds are reserve energy for germination as well as carbohydrates. The decrease amount of lipid after seed breaking-dormancy related to lipid metabolism through the glyoxyllic acid cycle. The cycle allows acetyl-CoA derived from the breakdown of storage lipids to be used for the synthesis of sugar [16], hence, this process increases the carbohydrate content of seeds. This result was in line with a significant association between lipid and carbohydrate content after seed dormancy-breaking, as...
presented in Table 4. A negative correlation was found between lipid and carbohydrate content, indicating that the decreasing amount of lipids will increase the amount of carbohydrate content.

A high amount of lipids in seeds may become a clue for its characteristic, which means seeds grouped as recalcitrant seed, seeds that are sensitive to low temperatures [17]. It means if we refer to the high amount of lipid in oil palm seed, the oil palm seed classified as recalcitrant seed. Oil palm seed were classified as an orthodox seed based on desiccation characteristics; seeds can be dried and stored at low temperatures [18]. However, oil palm seed also classified as an intermediate seed [between recalcitrant and orthodox seed] [19][20]. The intermediate seed means that seeds can be dried until less water amount like orthodox seeds; however, those are sensitive to low temperatures like recalcitrant seeds. Thus, the seed will overcome the dormancy problems, which was physiological dormancy [21], physical dormancy [8], or combination between morphological and physical dormancy [20][22].

Lignin, as well as cellulose and hemicellulose, are components of a seed coat. Lignin influences seed quality, including germination, hard seed, water permeability and resistance to seed deterioration [23]. Dura seeds have a thick seed shell that inhibits water and gas entering seeds. Lessening in the lignin content of dura genotypes due to a heat treatment at 40°C was essential to produce high germination of the genotypes. This phenomenon indicates that germination will occur after factors inhibited the germination removed.

3.2. Viability and vigor of oil palm seed

There was no seed from genotype Gh germinated [Table 3], probably because the seeds of genotype Gh were still in the dormancy phase. Seed dormancy-breaking have held on 40°C for 45 days might not suitable for Gh seed. Due to the thin of seed shell, pisifera seed is frail to face desiccation and microbes’ contamination. Besides, the length dormancy phase of pisifera seed caused its seeds are more difficult to germinate than dura and tenera [6][13][14]. There are some causes of this phenomenon, i.e. seeds lack embryos and the susceptibility of seed to infection by fungi and bacteria due to the absence or less of protective coating [shell] of seed [1][13]. Abnormalities in an embryo of pisifera seeds related to the partial until complete sterile of female inflorescences as reported by [24].

Table 3. Seed viability and vigor of oil palm genotype Gh, Ts, Ce, and Da after dormancy-breaking treatment at 40°C for 45 days

| Genotype | PTM | DB  | FCT | IVT |
|----------|-----|-----|-----|-----|
| Gh       | 0 c | 0 c | 0 c | 0 d |
| Ts       | 18.33 b | 18.33 b | 4.44 b | 1.05 c |
| Ce       | 98.89 a | 78.89 a | 9.44 b | 1.18 b |
| Da       | 100 a | 81.67 a | 21.11 a | 1.23 a |
| CV [%]   | 24.35 | 27.83 | 3.14 | 4.00 |

Means followed by the same letter in a column are not significantly different according to DMRT at P≥0.05. PTM: maximum potential growth [%]; DB: standard germination [%]; FCT: First Count Test [%]; IVT: Index Value Test; Data were transformed by \( \sqrt{(x+1)} \).

* Dura genotype seeds varied in viability and vigor. Seeds from genotypes Da and Ce showed the highest maximum potential growth [PTM] and seed germination [DB]. Genotype Da also showed the highest vigor based on the First Count Test [FCT] and the Index Value Test [IVT]. Seeds of genotype Ts did not show a high percentage of germination both for viability and vigor test, indicating that the genotype needs extended time to germinate. Exposure of heat treatment duration as seed dormancy-breaking up to 80 days as suggested by [1] can be applied. [6] reported that genotypes of oil palm seeds varied in the duration of breaking-dormancy by heat treatment.
3.3. Correlation between physical and chemical properties, viability, and vigor of seed

Table 4 showed the correlation coefficient between seed physical and chemical properties after seed dormancy-breaking treatment, and seed viability and vigor from three genotypes of Dura variety, i.e. genotype Ts, Ce, and Da.

Table 4. The correlation coefficient between oil palm seed physical and chemical properties, viability, and vigor

|       | BB  | KA  | KP  | KL  | KK  | KG  | PTM | DB  | FCT |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| KA    |     |     |     |     |     |     |     |     | 0.44*|
| KP    | -0.37 | -0.11 |     |     |     |     |     |     |     |
| KL    | -0.53* | -0.85** | 0.00 |     |     |     |     |     |     |
| KK    | 0.31 | 0.26 | 0.20 |     | -0.73** |     |     |     |     |
| KG    | -0.07 | -0.71** | -0.29 | 0.85** | -0.70** |     |     |     |     |
| PTM   | -0.68** | -0.66* | -0.01 | 0.90** | -0.75** | 0.62* |     |     |     |
| DB    | -0.58* | -0.58* | -0.10 | 0.84** | -0.75** | 0.59* | 0.96** |     |     |
| FCT   | -0.13 | -0.36 | -0.09 | 0.59* | -0.64* | 0.65* | 0.53* | 0.45* |     |
| IVT   | -0.40* | -0.58* | -0.23 | 0.85** | -0.79** | 0.71** | 0.90** | 0.96** | 0.46* |

BB: Seed Weight; Seed Water Amount; KP: Seed Protein Amount; KL: Seed Lipid Amount; KK: Seed Carbohydrate Amount; KG: Seed Lignin Amount; PTM: maximum potential growth; DB: seed germination; FCT: First Count Test; IVT: Index Value Test; ** and * significant at P<0.01 and P<0.05

Seed weight showed a negative correlation with lipid content. The negatively coefficient correlation was also found between seed moisture and lipid, as well as lignin content. Seed weight and water content correlated with the viability and vigor of seed. Seed weight significantly and negatively correlated to the maximum potential growth [PTM], seed germination [DB] and Index value test [IVT]. Those results are similar to [6], who reported that genotypes influenced seed germination and seedling quality. [25] categorized oil palm seeds of different Dura x Pisifera into several categories and confirmed that a seed weight influence the germination.

There was no correlation between protein content and viability and vigor of seed, indicating less contribution of protein as seed storage reserved in the germination process compared to carbohydrate and lipid. Lipid and lignin were positively correlated with seed viability and vigor, while carbohydrate was negatively correlated with seed viability and vigor. On vegetable oil-producing seed germination, the mobilization of lipid to acid on the seed is essential to supply the energy and carbon for seed growth. The lipolytic enzyme catalysis is the first process of lipid mobilization, which then controlled while and after the seed germination phase [26]. It means there is an association between lipid and carbohydrate amounts which become the energy supply for seed germination.

Viability and vigor traits correlated with each other. A very high coefficient correlation was found between maximum potential growth [PTB] and standard germination [DK]. The viability traits showed a higher correlation with an index value [IVT] compared to the ability of a seed to germinate earlier [FCT].
4. Conclusion
Each genotype of oil palm seed observed had different physical and chemical properties. Each genotype showed the response of a decreasing amount of water content, protein and lipid, and an increasing amount of seed carbohydrate after being held on 40°C as seed dormancy-breaking treatment. The heat treatment at 40°C for 45 days was not suitable for breaking dormancy of genotype Gh. Among the dura genotypes, Da genotype had the highest seed viability and vigor of seed. There were negative correlations between seed weight, water, and carbohydrate content with viability and vigor, while a positive correlation between lipid and lignin properties with viability and vigor. Seed protein content seems contributed less to germination compared to seed carbohydrate and lipid content.

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