(RESEARCH ARTICLE)

Functional characteristics of cocoa bean powder of the Mercedes and *Theobroma cacao* varieties from the Lôh-djiboua and Indenie-djuablin regions (Côte d'Ivoire)

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Abstract

The objective of this study is to reveal the existence of a difference in the functional properties of cocoa bean powders of the two varieties Mercedes and *Theobroma cacao* from two major cocoa producing areas of Côte d'Ivoire. For industrial use, the functional properties were determined using standard methods. It appears from this study that no significant difference was observed at the 5 % threshold ($P \geq 0.05$) in the mean apparent densities of the cocoa powders studied. The bulk density was 0.59 ± 0.01 g/mL for the Abengourou's Mercedes variety and 0.63 ± 0.01 g/mL for Abengourou's *Theobroma cacao*. On the other hand, a significant difference at the threshold of 5 % ($P \leq 0.05$) was observed in the averages of water absorption capacity, water solubility index and porosity of cocoa powders in the regions studied. The water absorption capacity is 213.29 ± 0.68 % for Abengourou's Mercedes and 279.25 ± 3.12 % for Divo's Mercedes. The water solubility index is 34.39 ± 0.65 % for Abengourou's Mercedes and 41.15 ± 0.65 % for Divo's Mercedes; the porosity is 22.58 ± 0.9 % for Abengourou's Mercedes and 31.72 ± 1.16 % for Divo's *Theobroma cacao*. The functional properties of the beans of the Mercedes and *Theobroma cacao* varieties analyzed and the statistical values allowed us to see that there is no significant variation from one region to another and from one variety to other both within the same region and outside the region. Research should, in addition to high productivity, be directed towards strengthening the rates of functional parameters.

Keywords: Mercedes; *Theobroma cacao*; Cocoa beans; Functional properties

1. Introduction

The cocoa tree (*Theobroma cacao L.*), is a food plant of the Malvaceae family and is native to South America and the Amazon [1, 2]. Three main varieties are produced in the world, namely: *Forastero* from Amazonia, which represents 70% of world production, *Criollo* grown in Central America and Asia represents 10% of world production and *Trinitario* grown all over the world represents 20% of world production [3]. World cocoa production is estimated at 3.6 million tonnes in 2010. West Africa is the main producer with more than 68% of world production [4]. With 40% of world production, Côte d'Ivoire remains the world's largest producer and exporter of cocoa with more than 1.8 million eight hundred and forty-eight thousand two hundred and thirty-three tonnes [5]. Several varieties of cocoa are grown in Côte d'Ivoire on different types of soil, we have among others varieties ''*Amelonado*'', ''*All coming*'' and Mercedes ... This last variety was developed in Côte d'Ivoire by the National Center for Agronomic Research (CNRA) in recent years. It should be noted that this variety Mercedes is the result of crossbreeding of old varieties and is characterized by a very short

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production cycle (18 months). Don't the varieties, soil types and climatic conditions of the different cocoa growing regions influence the functional properties of the cocoa bean powders?

Every year millions of children under the age of 5 die of hunger and malnutrition. These children suffer from nutritional deficiencies, avitaminosis and certain deficiencies in minerals essential for their health and physical development [6]. In an effort to combat malnutrition and nutritional deficiencies, we have undertaken to study the different functional properties of cocoa powders with a view to incorporating them into certain foods to enrich them and formulate new foods.

The main objective of this work is to contribute to food security in Côte d'Ivoire by enhancing the value of local products. Specifically, it involves the determination and comparison of the functional properties of the two varieties of cocoa beans, whether they are specific to a production area, or vary according to regions. This study will be carried out on cocoa beans of the Mercedes and *Theobroma cacao* varieties from the regions of Indenie-djuablin (Abengourou) and Lôh-djiboua (Divo). To achieve this, methods and equipment will be essential.

2. Material and methods

2.1. Material

2.1.1. Preparation of cocoa bean powder

Powder of cocoa pod beans is prepared according to the method described by [7]. Cocoa pod beans are crushed in a blender, after solar drying for a few days. The resulting grind is then sieved with a 125 μm mesh sieve and the powder produced is kept in the desiccator for the different manipulations (Figure 1).
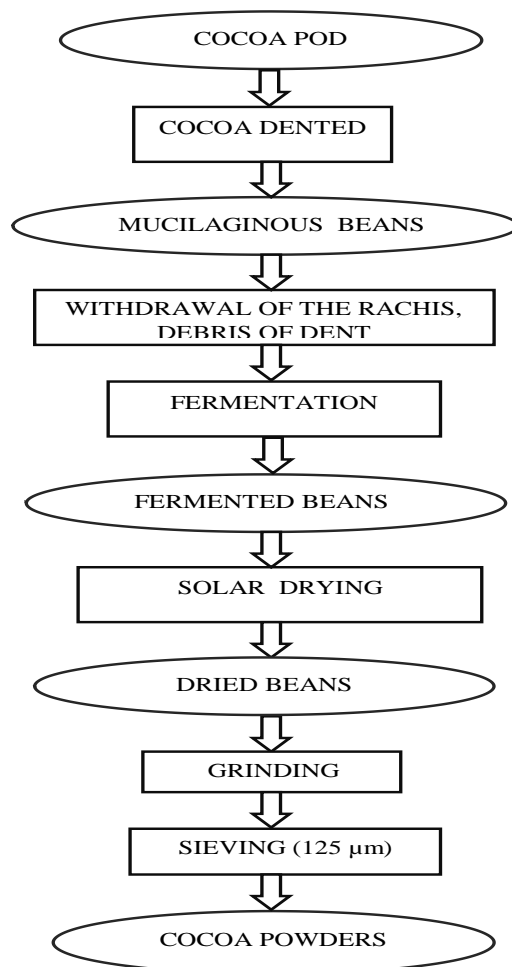
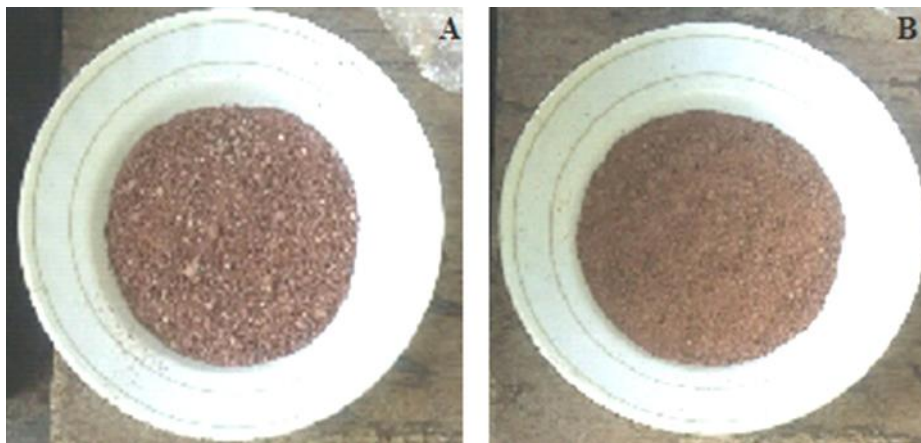**Figure 1** Diagram of the manufacture of cocoa bean powder

Figure 2 Photograph of bean powder (A: *Theobroma cacao* variety; B: Mercedes variety)**.**

2.2. Methods

2.2.1. Bulk density and porosity

The bulk density (DB) of the flour was determined according to the method of [8]. Fifteen (15) g (MS) of the sample was placed in a 100 mL graduated cylinder. The level of this flour was well levelled in the test tube and the volume (Vo) determined. Then, the tube was gently tapped on the bench until a constant volume was obtained, denoted Vt. The bulk density (DB) in (g/mL) and the porosity (P) in (%) were calculated according to the following mathematical relationships:

$$DB(g/mL) = \frac{MS}{Vt}$$

DB = bulk density

MS = sample mass

Vt = volume of sample noted after tapping

$$P(\%) = \frac{Vo - Vt}{Vo} \times 100$$

P = porosity

Vo = volume of sample noted after good levelling

Vt = volume of sample noted after tapping

2.2.2. Water Absorption Capacity (WAC) and Water Solubility Index (WSI)

The water absorption capacity (WAC) and the water solubility index (WSI) of the flours were determined by the method of [9], respectively. One (1) g (M0) of the bean flour was dissolved in 10 mL of distilled water contained in a centrifuge tube. After stirring for 30 min with a KS10 stirrer, the solution was kept in a water bath at 37 °C for 30 min. The resulting mixture was centrifuged at 5000 rpm for 15 min and the resulting wet pellet (M2) was weighed and then dried at 105 °C to a constant mass (M1). The water absorption capacity was calculated by the following formula:

$$WAC \ (\%) = \frac{M2 - M1}{M1} X \ 100$$

WAC: Water Absorption Capacity

M1: Mass of dried pellet

M2: Mass of the wet pellet

Water solubility index (WSI) was calculated by the following formula:

$$WSI \ (\%) = \frac{Mo - M1}{Mo} X \ 100$$

WSI: Water Solubility Index

Mo: Mass of the flour

M1: Mass of dried pellet

2.2.3. Oil Absorption Capacity (OAC)

The oil absorption capacity was determined according to the method of [10]. One (1) g of the bean flour was dispersed in 10 mL of (sunflower, dinor, red palm and olive) oil. After stirring for 30 min using a KS 10 stirrer, the mixture was centrifuged at 4500 rpm at 4 °C for 10 min and the supernatant was collected and the pellet was recovered and weighed (M1) on a SATORIUS precision balance. The oil absorption capacity (OAC) was calculated by the following formula:

$$OAC \ (\%) = \frac{M1 - Mo}{Mo} X \ 100$$

OAC: Oil Absorption Capacity

Mo: Flour mass

M1: Mass of the base

2.2.4. Hydrophilic Lipophilic Ratio

The hydrophilic-lipophilic ratio, as defined by [11], was calculated as the ratio of water absorption capacity to oil absorption capacity. This ratio makes it possible to evaluate the comparative affinity of flours for water and oil.

$$RHL = \frac{WAC}{OAC}$$

RHL = hydrophilic-lipophilic ratio

WAC = water absorption capacity

OAC = oil absorption capacity

2.2.5. Statistical analysis

The experiment was carried out in triplicate for functional analysis of cocoa beans powder. Data obtained were analyzed by Analysis of Variance (ANOVA) using the software RStudio version 1.1.456. Differences between means were tested using the Duncan Multiple Range Test with 5% level of significance.

3. Results and discussion

3.1. Functional properties

The functional properties (bulk density, porosity, water absorption capacity and water solubility index) of beans of the Mercedes and *Theobroma cacao* varieties from the regions of Lôh-djiboua (Divo) and Indenie-Djuablin (Abengourou) were studied and recorded in   Table 1.

The analysis of these results indicates that no significant difference at the 5 % threshold ($P \geq 0.05$) was observed in the mean apparent densities (Divo's Mercedes 0.60±0.01 g/mL; Divo's *Theobroma cacao* 0.61±0.01 g/mL); Abengourou's Mercedes 0.59±0.01 g/mL; Abengourou's *Theobroma cacao* 0.63±0.01 g/mL) of samples of beans of the Mercedes and *Theobroma cacao* varieties from the regions of Lôh-djiboua (Divo) and Indenie-djuablin (Abengourou).

On the other hand, a significant difference at the 5 % threshold ($P \leq 0.05$) was observed in the mean porosity (Divo's Mercedes 27.53±1.05 %; Divo's *Theobroma cacao* 31.72±1.16 %; Abengourou's Mercedes 22.58±0.9 %; Abengourou's *Theobroma cacao* 31.53±0.83 %), water absorption capacity (Divo's Mercedes 279.25±3.12 %; Divo's *Theobroma cacao* 249.92±1.03 %); Abengourou's Mercedes 213.29±0.68 %; Abengourou's *Theobroma cacao* 240.49±2.22 %) and of the water solubility index of the samples (Divo's Mercedes 41.15±0.65 %); Divo's *Theobroma cacao* 37.30±2.10 %; Abengourou's Mercedes 34.39±0.65 %; Abengourou's *Theobroma cacao* 40.83±1.22 %) of beans of the Mercedes and *Theobroma cacao* varieties.

Table 1 Functional properties of the powder of Mercedes and *Theobroma cacao* varieties of cocoa beans from the regions of Lôh-Djiboua (Divo) and Indenie-Djuablin (Abengourou).

Parameters	Regions	Varieties/Composition	
		Mercedes	*Theobroma cacao*
Bulk density (g/mL)	Lôh-djiboua (Divo)	0.60 ± 0.01[b]	0.61 ± 0.01[b]
	Indenie-djuablin (Abengourou)	0.59 ± 0.01[b]	0.63 ± 0.01[a]
Porosity (%)	Lôh-djiboua (Divo)	27.53 ± 1.05[b]	31.72 ± 1.16[a]
	Indenie-djuablin (Abengourou)	22.58 ± 0.9[c]	31.53 ± 0.83[a]
Water absorption capacity (%)	Lôh-djiboua (Divo)	279.25 ± 3.12[a]	249.92 ± 1.03[b]
	Indenie-djuablin (Abengourou)	213.29 ± 0.68[d]	240.49 ± 2.22[c]
Water solubility index (%)	Lôh-djiboua (Divo)	41.15 ± 0.65[a]	37.30 ± 2.10[b]
	Indenie-djuablin (Abengourou)	34.39 ± 0.65[c]	40.83 ± 1.22[a]

For each component, on the rows and columns, the means ± standard deviations affected, of different letters are significantly different from each other at the threshold of p ≤ 0.05 according to Duncan's test

3.2. Oil absorption capacity of beans

The oil absorption capacity of cocoa bean powder of the Mercedes and *Theobroma cacao* varieties from the regions of Lôh-djiboua (Divo) and Indenie-djuablin (Abengourou) was studied and recorded in Table 2.

The oil absorption capacity of the beans was verified in different oils found on the market, namely palm dinor oil (Divo's Mercedes 47.00±5.50 %; Divo's *Theobroma cacao* 66.85±8.15 %; Abengourou's Mercedes 33.41±2.32 %; Abengourou's *Theobroma cacao* 62.08±2.76 %), red palm oil (Divo's Mercedes 126.95±2.24 %; Divo's *Theobroma cacao* 71.45±4.15 %); Abengourou's Mercedes 84.45±2.25 %; Abengourou's *Theobroma cacao* 118.03 ± 2.31 %), olive oil (Divo's Mercedes 55.65±5.05 %; Divo's *Theobroma cacao* 74.40±3.60 %; Abengourou's Mercedes 45.61±2.00 %; Abengourou's *Theobroma cacao* 63.43±2.3 %) and sunflower oil (Divo's Mercedes 74.60±2.87 %; Divo's *Theobroma cacao* 57.50±1.15 %; Abengourou's Mercedes 53.66±2.3 %; Abengourou's *Theobroma cacao* 53.05±2.70 %).

A significant difference at the threshold of 5 % of the average absorption capacity in different bean oils was found (P≤0.05 %).

Table 2 Oil absorption capacity of beans of the Mercedes and *Theobroma cacao* varieties from the regions of Lôh-Djiboua (Divo) and Indenie-Djuablin (Abengourou)

Parameters	Regions	Varieties/Composition	
		Mercedes	*Theobroma cacao*
OAC % (Dinor)	Lôh-djiboua (Divo)	47.00 ± 5.50[b]	66.85 ± 8.15[a]
	Indenie-djuablin (Abengourou)	33.41 ± 2.32[c]	62.08 ± 2.76[a]
OAC % (Palm Red)	Lôh-djiboua (Divo)	126.95 ± 2.24[a]	71.45 ± 4.15[d]
	Indenie-djuablin (Abengourou)	84.45 ± 2.25[c]	118.03 ± 2.31[b]
OAC % (Olive)	Lôh-djiboua (Divo)	55.65 ± 5.05[c]	74.40 ± 3.60[a]
	Indenie-djuablin (Abengourou)	45.61 ± 2.00[d]	63.43 ± 2.3[b]
OAC % (sunflower)	Lôh-djiboua (Divo)	74.60 ± 2.87[a]	57.50 ± 1.15[b]
	Indenie-djuablin (Abengourou)	53.66 ± 2.3[bc]	53.05 ± 2.70[c]

For each component, on the rows and columns, the means ± standard deviations affected, of different letters are significantly different from each other at the threshold of p ≤ 0.05 according to Duncan's test

3.3. Hydrophilic-lipophilic ratio of beans

The hydrophilic-lipophilic ratio was calculated to see the affinity of the beans for water or oil. The hydrophilic-lipophilic ratio for each oil was calculated investigated and reported in Table 3.

In the view of the table, the hydrophilic-lipophilic ratio of each of the oils studied shows a significant difference at the threshold of 5 % (P≤0.05).

Table 3 Hydrophilic-lipophilic ratio of Mercedes and *Theobroma cacao* beans from the regions of Lôh-djiboua (Divo) and Indenie-Djuablin (Abengourou)

Components	Regions	Varieties/Composition	
		Mercedes	*Theobroma cacao*
RHL(Dinor)	Lôh-djiboua (Divo)	5.94±0.0[b]	3,74±0.0[d]
	Indenie-djuablin (Abengourou)	6.38±0.0[a]	3,97±0.0[c]
RHL(Red Palm)	Lôh-djiboua (Divo)	2.2±0.0[c]	3,5±0.0[a]
	Indenie-djuablin (Abengourou)	2.53±0.0[b]	2,04±0.0[d]
RHL(Olive)	Lôh-djiboua (Divo)	5.02±0.0[a]	3,36±0.0[d]
	Indenie-djuablin (Abengourou)	4.68±0.0[b]	3,81±0.0[c]
RHL(Sunflower)	Lôh-djiboua (Divo)	3.75±0.0[d]	4,35±0.0[b]
	Indenie-djuablin (Abengourou)	3.98±0.0[c]	4,53±0.0[a]

For each component, on the rows and columns, the means ± standard deviations affected, of different letters are significantly different from each other at the threshold of p ≤ 0.05 according to Duncan's test

4. Discussion

This study allowed the functional properties of the cocoa powder of the Mercedes and *Theobroma cacao* varieties to be demonstrated. Different analyses were carried out and have allowed us to have the results that we will discuss.

Concerning bulk density (Divo's Mercedes 0.60±0.01[b] g/mL; Divo's *Theobroma cacao* 0.61±0.01[b] g/mL; Abengourou's Mercedes 0.59±0.01[b] g/mL); Abengourou's *Theobroma cacao* 0.63±0.01[a] g/mL), it affects the particle size of flours and plays an important role during mixing (as in dough formation), sorting, packaging and transport of food particles [12].

The bulk density of cocoa powder ranges from 0.59±0.01 g/mL for beans of the Mercedes variety from the Indenie-djuablin region (Abengourou) to 0.63±0.01 g/mL for beans of the *Theobroma cacao* variety from Abengourou. In addition, the values of apparent densities of rice flour grown in Nigeria (0.65 to 0.79 g/mL) are approximately equal to that of the powder studied for the Abengourou's *Theobroma cacao* variety 0.63±0.01 g/mL [13]. Low bulk densities (Divo's Mercedes 0.60±0.01 g/mL; Divo's *Theobroma cacao* 0.61±0.01 g/mL; Abengourou's Mercedes 0.59±0.01 g/mL) are desirable for the preparation of baby weaning foods [14]. They are important in the feed separation process such as sedimentation, centrifugation [15]. The Mercedes varieties of Divo and Abengourou and the Divo's *Theobroma cacao* variety have the same porosity and differ from the Abengourou's *Theobroma cacao*.

The porosity of flour is a measure of flour weight. It determines the suitability of a flour to be easily packaged, which would facilitate the transport of a large quantity of food. Nutritionally, high porosity promotes the digestibility of food products, especially in children because of their immature digestive systems [16, 17, 18]. The porosity of cocoa powders is 22.58±0.9[c] % for Mercedes variety beans from the Indenie-Djuablin region (Abengourou) and 31.72±1.16[a] % for *Theobroma cacao* variety beans from the Lôh-djiboua region (Divo). These values are roughly equal to those of taro bulb flours (31.8 to 33.2 %) and lower than those of bread flours ranging between 43.1 and 54.8 % [19, 20]. Porosities higher than 25 % may be useful in infant food formulation. The *Theobroma cacao* variety of Divo and Abengourou has good porosity compared to the Mercedes variety of Divo and Abengourou. Flour porosity is an important factor in the food industry. Indeed, it highlights the elasticity, viscosity and swelling properties of flour.

Water absorption capacity (WAC) is an index of the maximum amount of water that a food product can absorb and hold. It is important for certain product characteristics, such as product wetting and starch retrogradation [21, 22].

Our study has shown that the percentage of water absorption of cocoa powders is Divo's Mercedes 279.25±3.12[a] %; Divo's *Theobroma cacao* 249.92±1.03[b] %; Abengourou's Mercedes 213.29±0.68[d] %; Abengourou's *Theobroma cacao* 240.49±2.22[c] %. The value of Divo's Mercedes 279.25±3.12[a] % is higher than that found by [23] for the results of his work on bean and cowpea flours 275 %. The water absorption capacity of cocoa powders (WAC) differs from the Mercedes varieties of Divo and Abengourou and the *Theobroma cacao* varieties of Divo and Abengourou.

The high WAC value of the powders of the Mercedes and *Theobroma cacao* varieties of beans would be more related to their protein content than to their lipid content. This is because the availability of protein functional groups in flours is governed by the water absorption capacity which is an important property of flours used in pastry making [24].   [25] Indicates that proteins are mainly responsible for most of the water absorption.

The presence of lipids in large quantities in a flour would reduce the water's ability to bind to specific substances, thereby limiting the WAC [18].

On the other hand, according to [26], flours with high water absorption are more hydrophilic. This hydrophilicity would be due to polysaccharides. Therefore, the high values of water absorption in these flours could be attributed to the presence of a large amount of hydrophilic constituents.

The increased water absorption capacity of cocoa beans could also be attributed to the presence of higher amounts of carbohydrates in these flours [27].

The high WAC of cocoa beans suggests that they could be useful in soup formulations for easier digestion [28].

The water solubility index (WSI) reflects the extent of starch degradation [29]. The percentage of the WSI is (Divo's Mercedes 41.15±0.65[a] %; Divo's *Theobroma cacao* 37.30±2.10[b] %; Abengourou's Mercedes 34.39±0.65[c] %; Abengourou's *Theobroma cacao* 40.83±1.22[a] %). Divo's Mercedes and Abengourou's *Theobroma cacao* have the same solubility index and differ from Divo's Mercedes and Abengourou's *Theobroma cacao*.

The water solubility index of Divo and Abengourou's Mercedes and *Theobroma cacao* varieties is higher than that of raw taro flour (10 % to 27 %) found by [29]. The water solubility index cannot be attributed solely to starch degradation. Proteins, total sugars and crude fats could play an important role in this change in functional properties. This physic-functional characteristic plays an important role in the choice of flours to be used as thickeners in the food industry [30].

In view of the results obtained we can say that the *Theobroma cacao* variety of Divo and Abengourou has a good porosity, a medium water absorption capacity, a higher bulk density and a more interesting solubility index than the Mercedes

variety from both regions. The level of functional parameters of the Mercedes varieties needs to be increased for better use in the food industry.

The absorption capacity (OAC) in red palm oil of 84.45±2.25[c] % observed in the Abengourou's region is lower than that observed in the Divo's region 126.95±2.24[a] % for beans of the Mercedes variety. Whereas for beans of the *Theobroma cacao* variety, the absorption capacity in red palm oil (71.45±4.15[d] %) in the Divo's region is lower (118.03±2.31[b] %) in the Abengourou's region. However, our values are well below the OAC (220.33±1.31 %) demonstrated by [31] in the larvae of the caterpillar Oryctes owariensis. The absorption capacity (OAC) in red palm oil of cocoa powders of the Mercedes varieties of Divo and Abengourou differ from the *Theobroma cacao* varieties of Divo and Abengourou.

The high OAC (Divo's Mercedes 126.95±2.24[a] % and Abengourou's *Theobroma cacao* 118.03±2.31[b] %) in red palm oil could be good lipophilic constituents and therefore suitable for the preparation of sausages, soups and cakes. The oil absorption capacity (OAC) is an important property in food formulation, because the oil improves the flavour and gives the food a soft texture [32].

The values of the hydrophilic-lipophilic ratio obtained in this study are higher than 1, so this would mean that the cocoa bean powder of the Mercedes and *Theobroma cacao* varieties has more affinity for water than for the different oils studied. This suggests that our powders should preferably be used for the formulation of products requiring a high water absorption capacity.

In the refined oils (dinor and olive), the powders of the Mercedes variety beans from Divo and Abengourou have a higher affinity for the oils compared to the *Theobroma cacao* variety beans. Whereas in unsaturated oil (red palm oil), beans of the Divo's *Theobroma cacao* variety (RHL=3.5) have a higher affinity for oil than those of the Divo's Mercedes (RHL=2.2) and Abengourou (RHL=2.53) varieties.

5. Conclusion

At the end of this study, we found that in terms of the functional potential of cocoa powders, the differences between the Mercedes and *Theobroma cacao* varieties are in the parameters of water absorption capacity and porosity in the regions of Lôh-Djiboua (Divo) and Indenie-Djuablin (Abengourou). The *Theobroma cacao* variety from both regions has good porosity compared to the Mercedes variety from both regions. Divo's Mercedes variety has a higher water capacity (WAC) than Divo's and Abengourou's *Theobroma cacao* variety. In saturated refined oils (Dinor, Olive) the *Theobroma cacao* variety from both regions absorbs more oil than the Mercedes variety from Divo and Abengourou. Except for unsaturated red palm oil, Divo's Mercedes variety has a higher oil absorption capacity (OAC) than the *Theobroma cacao* variety from both regions. The powder of Divo's and Abengourou's *Theobroma cacao* varieties has more interesting techno-functional properties than Abengourou's Mercedes variety. The Mercedes variety needs to be strengthened in functional properties to be more useful in the food industry.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

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How to cite this article

Karim KJC, Saki SJ, Sea TB, Yoboué GAKL and Soro YR. (2020). Functional characteristics of cocoa bean powder of the Mercedes and *Theobroma cacao* varieties from the Lôh-djiboua and Indenie-djuablin regions (Côte d'Ivoire). GSC Biological and Pharmaceutical Sciences, 12(1), 62-71.