Detarium microcarpum Guill. & Perr. fruit properties, processing and food uses. A review

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Focus on:

Detarium microcarpum Guill. & Perr. fruit properties, processing and food uses. A review

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Introduction. *Detarium microcarpum* is a woody fruit plant, widely found in the dense dry and clear forests of sub-Saharan Africa. This review presents the nutritional and functional properties of *D. microcarpum* fruits pulp and seed, as well as their uses in food products.
Literature. The two edible parts of the fruit of *D. microcarpum* are pulp and seed. These pulp and seed have an almost identical carbohydrate content (40.2-66.1%). Pulp contains proteins (2.9-6.1%), lipids (0.7-2.2%), and minerals: magnesium (51-84 mg·100g^{-1}), potassium (1,017 mg·100g^{-1}) and vitamins (vitamin C: 4.6-4.7 mg·100g^{-1}). Seed also contains proteins (34.5-37.1%), lipids (23%), minerals and vitamins (vitamin C: 9.3-28.1 mg·100g^{-1}). Seed powder exhibits functional properties such as bulk density (0.5-0.9 g·cm^{-3}), water absorption capacity (3.5-11.7 ml·g^{-1}), oil absorption capacity (0.7-3.1 ml·g^{-1}), solubility (2-3%), emulsion capacity (4.3-4.4%), emulsion stability (3.4-3.5%), foaming capacity (8.7-8.8 cm^{3}) and foam stability (7.0-9.3 cm^{3}); it also improves the viscosity of dough. Pulp is used in juice and jam, while seeds are used as a stabilizer or as a thickener in juice, jam, tomato sauce, traditional soup, white bread, raw beef burger, and ice cream.
Conclusions. Most studied works on the seed of *D. microcarpum* did not explore beyond the properties of its gum. Likewise, those on the pulp only approached its use in juice and jam. Therefore, it presents a large possibility for research in the context of the formulation of foods containing *D. microcarpum* fruits.
Keywords. Food composition, food processing, fruit trees, functional foods, fruit products.

Propriétés, transformation et utilisations alimentaires des fruits de *Detarium microcarpum* Guill. & Perr. (synthèse bibliographique)

Introduction. *Detarium microcarpum* est une plante fruitière ligneuse, largement présente dans les forêts de l'Afrique subsaharienne. Cette revue présente les propriétés nutritionnelles et fonctionnelles des fruits de *D. microcarpum* et leurs utilisations dans différents produits alimentaires.
Littérature. Les deux parties comestibles du fruit de *D. microcarpum* sont la pulpe et la graine. Ces pulpes et graines ont un taux de glucides presque identique (40,2-66,1 %). La pulpe contient des protéines (2,9-6,1 %), des lipides (0,7-2,2 %), des minéraux : magnésium (51-84 mg·100 g^{-1}), potassium (1017 mg·100 g^{-1}) et des vitamines (vitamine C : 4,6-4,7 mg·100 g^{-1}). La graine aussi contient des protéines (34,5-37,1 %), des lipides (23 %), des minéraux et des vitamines (vitamine C : 9,3-28,1 mg·100 g^{-1}). La poudre des graines présente des propriétés fonctionnelles : masse volumique apparente (0,5-0,9 g·cm^{-3}), capacité d'absorption d'eau (3,5-11,7 ml·g^{-1}), capacité d'absorption d'huile (0,7-3,1 ml·g^{-1}), solubilité (2,0-3,0 %), capacité d'émulsion (4,3-4,4 %), stabilité de l'émulsion (3,4-3,5 %), pouvoir moussant (8,7-8,8 cm^{3}) et stabilité de la mousse (7,0-9,3 cm^{3}) ; elle améliore également la viscosité de la pâte. La pulpe de *D. microcarpum* est utilisée dans les jus et confitures, tandis que la graine est utilisée comme stabilisant ou épaississant dans le jus, la confiture, la sauce tomate, la sauce traditionnelle, le pain blanc, le hamburger et la crème glacée.

Conclusions. La plupart des travaux étudiés sur la graine de *D. microcarpum* n'ont pas exploré au-delà des propriétés de sa gomme. De même, ceux sur l'utilisation de la pulpe n'ont abordé que le jus et la confiture. Il se présente dès lors une large possibilité de recherche dans le contexte de la formulation des aliments à base des fruits de *D. microcarpum*.
Mots-clés. Composition des aliments, traitement des aliments, arbre fruitier, aliment fonctionnel, confiture.

1. INTRODUCTION

The World Health Organization reports that "wild" plants may support the health and nutritional needs of 80% of people living in developing countries (Van Andel, 2006). Non-timber forest products (NTFPs) would therefore represent a considerable food and economic stake for local populations. In addition, it is recognized that rational exploitation of local resources, through improved processing technologies, would make a valid contribution to the sustainable development of the continent (Issaoui-Mansouri, 2010). *Detarium* spp. were identified among the NTFPs of major importance in Africa. The genus *Detarium* spp. belongs to the class of Magnoliopsida, subclass of Rosidae, order of Fabales, family of Fabaceae, subfamily of Caesalpinioideae, tribe of Detarieae (Kouyate, 2005). *Detarium* has several species including *Detarium microcarpum* Guill. & Perr. (Akah et al., 2012). *Detarium microcarpum* inhabits dry lands, wooded savannas, and open forests of the Sudano-Guinean and Sudano-Sahelian zones of the African continent (Arbonnier, 2002). Its range extends from Senegal to Sudan, in particular in Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Mali, Niger, Nigeria, Central African Republic, Senegal, Sudan and Chad (Kouyate, 2005). It is known as: "sweet dattock" or "tallow tree" or "sweet Detar" in English and "Détar sucré" or "petit Détar" in French. It is a fruit tree of great socio-economic importance in West Africa (Agbo et al., 2017). The pulp of this fruit is known to be rich in sugar, vitamin C and certain minerals (Makalao et al., 2016). The seed contained in the stone of the fruit is also rich in nutritional and functional properties and has the particularity of being rich in hydrocolloids ($59.8\ g \cdot 100\ g^{-1}$) which gives it binding and thickening properties (Uzomah & Odusanya, 2011). Indeed, *D. microcarpum* seeds powder revealed several functional and pasting properties such as: water and oil absorption, foaming ability, emulsion capacity, swelling power and very good aptness for use as stabilizer or thickening agent (Onweluzo et al., 1999a; Onweluzo et al., 1999b; Akpata & Miachi, 2001; Amandikwa et al., 2017; Peace & Adekunle, 2018). It is also proven that the processing method of *D. microcarpum* pulp or seed has a considerable effect on these different properties (Amandikwa et al., 2017; Peace & Adekunle, 2018; Michael et al., 2019). Consequently, this review aims to present an updated report of the nutritional and functional properties of pulp and seed of *D. microcarpum* fruit, to highlight the effect of processing methods on these properties and finally to make an inventory of their use in food products. To achieve these objectives, data collection has been done in scientific databases such as: Web of science, Scopus/Science Direct, Springer, Wiley, MDPI, and Google Scholar. The following expressions and keywords were used: *Detarium microcarpum*, fruit of *Detarium microcarpum*, seed of *Detarium microcarpum*, nutritional and functional properties of fruits of *Detarium microcarpum*, use of fruits of *Detarium microcarpum*. More than 120 original articles and 2 review articles were obtained. The selection according to the objectives made it possible to retain 43 original articles and 2 review articles. In the article analysis, priority was given to the most recent articles, especially those less than 10 years old. These selected articles were arranged by categories, which at the same time correspond to the structure of the development of this review, including:

– generalities;
– nutritional and functional properties;
– effects of processes on the properties of *D. microcarpum* seed;
– use of the pulp and seed of the fruits of *D. microcarpum* in food products.

2. LITERATURE

2.1. Morphological characterization and conservation of *D. microcarpum*

Detarium microcarpum is a shrub or small tree with an irregular crown, 5-10 m tall (**Figure 1a**). The tree is recognizable by its leaves, 15 cm long, paripinnate or imparipinnate (Arbonnier, 2002; Akah et al., 2012), with translucent ones. They contain four to twelve alternate or sub-opposite leaflets 11 cm long and 3 to 5 cm wide (Arbonnier, 2002). The bark is reddish brown, cracked on woody twigs, clear, smooth, and greenish yellow on young shoots; its flowers are grouped in axillary panicles 15 to 25 cm long and 6 to 10 cm wide (Kouyate, 2005; Akah et al., 2012). The fruit of *D. microcarpum* (**Figure 1b**) is a globular or sub globular, flattened drupe 3 to 8 cm in diameter. According to Kouyate (2005), it is made up of three

Figure 1. *Detarium microcarpum*: tree (**a**), fruits (**b**), pulp (**c**) and seeds (**d**) — Detarium microcarpum: *arbre (**a**), fruits (**b**), pulpe (**c**) et graines (**d**).*

Source : D. Tchatcha.

main parts: the epicarp (dark green, hard for immature fruits, light green tending to brown and brittle for ripe fruits), the greenish mesocarp or pulp (**Figure 1c**), intermingled with fibers inserted on the stone corresponding to the edible portion of the fruit, and the stone (**Figure 1d**), woody, covered with fibrous meshes containing a single ovoid and flattened seed of dark brown color. The fruits develop between early January and May, while ripening happens between February and April in arid sub-Saharan Africa from Senegal east to Sudan (Kouyate & Lamien, 2011). In Mali, the average fruit production of a population of *D. microcarpum* possessing 268 trees·ha^{-1} reaches 1.6 ton·ha^{-1} of fruits (Kouyate et al., 2016). *Detarium microcarpum* is among threatened species (Agbo et al., 2017). The main threats facing *Detarium* species are the massive harvesting of leaves, roots and stems and especially logging for wood. Excessive logging, mainly for fuel, the expansion and intensification of agriculture, and uncontrolled fires prevent regeneration in *D. microcarpum*. Today, trees with trunks larger than 30 cm in diameter are rarely found within a 10 km radius of villages (Kouyate & Lamien, 2011). Perhaps the best conservation strategy for *D. microcarpum* is to encourage the use of its fruits in food and also through a well-planned domestication process (Kouyate & Lamien, 2011). Identifying areas of abundance that can serve as *in situ* conservation areas and setting up seed banks would contribute to the conservation of *D. microcarpum* (Agbo et al., 2017). *Detarium microcarpum* can be propagated either by seed, or by stump rejection, or by sucker (Kouyate, 2005). The seeds are orthodox. Propagation by seed requires pretreatment with boiling water or sulfuric acid, then soaking in lukewarm water for 24 h or cutting the hard seed coat with a sharp object. Germination *in situ* is favored by the intervention of phytophagous termites which bury the fruit of *D. microcarpum* by their constructions and thus maintain a certain humidity around it, even on skeletal soils. By vegetative propagation, *D. microcarpum* has a great capacity for vegetative multiplication by regeneration in coppice and suckering of stumps or roots. Also lateral root segments, measuring 20 cm in length and 15 to 60 mm in diameter and from mature cultivated trees, can be used for cuttings of the species in the nursery (Kouyate, 2005).

2.2. Nutritional and functional properties of *D. microcarpum* fruit pulp and seed

Pulp. The fruit pulp of *D. microcarpum* contains a relatively low moisture (**Table 1**). The values are between 7.1 and 12.2% (Kini et al., 2010; Oibiokpa et al., 2014; Makalao et al., 2016). The carbohydrate content is the highest among the main constituents, it varies from 40.1 to 65.4% (Mariod et al., 2009; Oibiokpa et al., 2014; Makalao et al., 2016) and represents more than 81.2% of the dry matter of dried pulp (Kini et al., 2010). Proteins vary from 2.9 to 6.12% (Kouyate et al., 2009; Kini et al., 2010; Oibiokpa et al., 2014; Makalao et al., 2016). However, Mariod et al. (2009) found a protein level of up to 30.0% ± 0.4 on the pulp of *D. microcarpum* fruits collected in Sudan. The lipid content of the pulp of *D. microcarpum* is between 0.7 and 2.2% (Mariod et al., 2009; Kini et al., 2010; Oibiokpa et al., 2014; Makalao et al., 2016). The vitamin C content varies from 4.6 to 4.7 mg·100 g^{-1} (Kouyate et al., 2009; Makalao et al., 2016), but Oibiokpa et al. (2014) found 55.1 mg·100 g^{-1}. Magnesium (51-84 mg·100 g^{-1}), a fundamental trace element for the cell, is also present at interesting levels in the pulp (Kini et al., 2010; Makalao et al., 2016). The pulp of *D. microcarpum* fruit is also very rich in potassium (1.017 mg·100 g^{-1}) (Kini et al., 2010). The potassium content is comparable to those of almond fruits (600 mg·100 g^{-1}) and potatoes (500 mg·100 g^{-1}) classified as foods rich in potassium (Alais & Linden, 1991). According to Oibiokpa et al. (2014) and

Table 1. Nutritional properties of *Detarium microcarpum* fruit pulp — *Propriétés nutritionnelles de la pulpe de fruit de* Detarium microcarpum (Umaru et al., 2007; Kouyate et al., 2009; Kini et al., 2010; Florence et al., 2014; Makalao et al., 2016).

Nutritional properties	Values
Moisture (%)	7.1-12.2
Ash (%)	3.0-3.1
Crude fiber (%)	12.2
Fat (%)	0.7-2.2
Proteins (%)	2.9-6.1
Carbohydrates (%)	40.1-65.4
Energy (Kcal·100 g^{-1})	239.4-241.0
Calcium (mg·100 g^{-1})	26.2-43.0
Iron (mg·100 g^{-1})	47.3-106.3
Magnesium (mg·100 g^{-1})	51.3-84.0
Sodium (mg·100 g^{-1})	112.0
Potassium (mg·100 g^{-1})	1017.0
Phosphorus (mg·100 g^{-1})	9.0
Zinc (mg·100 g^{-1})	5.9-9.9
Zeaxanthin (μg·100 g^{-1})	410
Kryptoxanthin (μg·100 g^{-1})	367.3
β-Carotene (μg·100 g^{-1})	312.7
Vitamin C (mg·100 g^{-1})	4.6-4.7
Vitamin E (mg·100 g^{-1})	1.2
Vitamin B2 (mg·100 g^{-1})	0.4
Vitamin K (μg·100 g^{-1}	312.2
Tannins (mg·100 g^{-1})	0.2-0.4
Phytic acid (mg·100 g^{-1})	0.2-0.4
Saponins (mg·100 g^{-1})	1.2-2.7
Oxalates (mg·100 g^{-1})	1.1-1.3
Cyanides (mg·100 g^{-1})	0.1

Umaru et al. (2007), the fruit of *D. microcarpum*, like most wild fruits, contains small amount of anti-nutritional compounds such as: saponin (1.2-2.7 mg·100 g^{-1}), oxalate (1.1-1.3 mg·100 g^{-1}), phytate (0.2-0.4 mg·100 g^{-1}), tannins (0.2-0.4 mg·100 g^{-1}) and cyanides (0.1 mg·100 g^{-1}).

With regard to the nutritional contribution of the pulp of *D. microcarpum* fruit, the contents of vitamin C, calcium, magnesium and protein are lower than the daily allowances recommended by FAO/WHO (vitamin C, 45 mg·day^{-1}; calcium, 1,000 mg·day^{-1}; magnesium, 220-260 mg·day^{-1}; protein, 13.5-15.5 g·day^{-1}. However, the iron content (47.3-106.3 mg·100 g^{-1}) can meet the daily intake recommended by FAO/WHO (2004), 27.4-58.8 mg·day^{-1}. In addition, the zinc content (5.9-9.9 mg·100 g^{-1}) is lower than the daily intake recommended by FAO/WHO for girls aged 10-18 (14.4 mg·day^{-1}) and men aged 10-65 years and over (14-17.1 mg·day^{-1}), but may satisfy women aged 19 to 65 and over (9.8 mg·day^{-1}). This is the reason why Makalao et al. (2016) and Oibiokpa et al. (2014) concluded that the integration of *D. microcarpum* fruit pulp in combination with other foodstuffs in the daily diet could overcome the challenges associated with the lack of carbohydrates in terms of energy, mineral and vitamin C intakes.

Seed. Several studies show that *D. microcarpum* seeds contain (**Table 2**) a relatively low moisture, values ranging from 2.2 to 16.7% (Akpata & Miachi, 2001; Uhegbu et al., 2009; Amandikwa et al., 2017; Peace & Adekunle, 2018; Michael et al., 2019). Low values (2.2-9.9%) were found by Akpata & Miachi (2001), Peace & Adekunle (2018), Michael et al. (2019) and the highest values (11.7-16.7%) were found by Uhegbu et al. (2009) and Amandikwa et al. (2017). The sugar content is the highest among the main constituents, ranging from 39.0 to 66.1% dry matter (Akpata & Miachi, 2001; Anhwange et al., 2004; Uhegbu et al., 2009; Amandikwa et al., 2017; Peace & Adekunle, 2018). For proteins, the highest levels have been evaluated between 34.5 and 37.1% by Akpata & Miachi (2001), Anhwange et al. (2004); the lowest values (8.8-17.7%) were found by Uhegbu et al. (2009), Amandikwa et al. (2017), Peace & Adekunle (2018), Michael et al. (2019). For fats, they range from 1.01% (Peace & Adekunle, 2018) to 23% (Amandikwa et al., 2017). Other authors found intermediate values (Akpata & Miachi, 2001; Anhwange et al., 2004; Uhegbu et al., 2009; Michael et al., 2019). The fat content of *D. microcarpum* seeds is low (about 7%). Apart from oleic acid (29.1%), behenic acid (25.4%), palmitic acid (12.5%) and lignoceric acid (11%), fat from the seeds of *D. microcarpum* contains beta-carotene, plant sterols, phospholipids and glycolipids (Sowemimo et al., 2011). Several toxicological studies show the absence of gossypol and detectable mycotoxins. The works of Anhwange et al. (2004) showed that the fat of the seeds of *D. microcarpum* does not oxidize quickly and remain a long time under liquid form. They also showed that this fat can be kept during a long period. These works allowed them to deduct that the fat of the seeds of *D. microcarpum* can be used in the human and animal food (Anhwange et al., 2004). Fairly similar values for fibers and ash were found, ranging between 1 and 7% (Akpata & Miachi, 2001; Uhegbu et al., 2009; Amandikwa et al., 2017; Peace & Adekunle, 2018; Michael et al., 2019). Most authors have used standard conventional methods for analyzing these key constituents. *Detarium*

Table 2. Effect of processing methods on nutrients and anti-nutrients of *Detarium microcarpum* seeds — *Effet des méthodes de transformation sur les nutriments et les anti-nutriments des graines de* Detarium microcarpum (Obun et al., 2009; Uhegbu et al., 2009; Amandikwa et al., 2017; Peace et al., 2018; Michael et al., 2019).

Nutrients/anti-nutrients	Raw	Roasted or toasted	Boiled	Soaked	Fermented
Moisture (%)	7.2-16.7	6.8-11.7	7.3-12.4	7.3-15.3	7.9
Ash (%)	4.5	2.1-7.2	2.3-5.8	3.5-5.9	5.3
Crude fiber (%)	5.3	4.3-7.1	3.2-5.0	3.9-5.2	4.8
Fat (%)	7.6	5.7-16.4	4.7-16.1	3.7-23.0	8.0
Proteins (%)	12.6	13.9-17.7	14.4-15.6	12.9-14.9	16.8
Free nitrogen extracted (%)	62.9	56.7	61.2	61.7	57.2
Carbohydrates (%)	52.2-57.0	46.8-66.1	50.4-61.3	41.1-62.3	64.7
Energy (Kcal·100 g^{-1})	341.1-396.1	329.4-375.1	346.4-398.0	342.1-397.6	345.2-399.9
Calcium (g·100 g^{-1})	0.234-0.35	0.213-0.291	0.185-0.212	0.194-0.238	0.261
Iron (g·100 g^{-1})	0.012	0.016	0.01	0.013	0.0158
Magnesium (g·100 g^{-1})	0.102-0.24	0.174-0.196	0.122-0.194	0.116-0.187	0.143
Sodium (g·100 g^{-1})	0.13-0.24	0.349	0.177	0.251	0.317
Potassium (g·100 g^{-1})	1.457-1.5	1.836	1.044	1.539	1.677
Phosphorus (g·100 g^{-1})	0.15-0.206	0.141-0.275	0.157-0.231	0.152-0.224	0.241
Vitamin A (IU·100 g^{-1})	4157.3	986.3	2645.8	4571.4	5364.1
Vitamin B1 (mg·100 g^{-1})	0.32	0.18	0.26	0.34	0.36
Vitamin B3 (mg·100 g^{-1})	0.23	0.09	0.18	0.25	0.29
Vitamin B6 (mg·100 g^{-1})	0.16	0.04	0.12	0.17	0.21
Vitamin C (mg·100 g^{-1})	21.46	9.32	18.63	23.45	28.05
Vitamin D (mg·100 g^{-1})	0.26	0.34	0.28	0.25	0.42
Tannins (mg·100 g^{-1})	0.36-0.8	0.21-0.44	0.67-0.68	0.34-0.71	0.74
Phytic acid (mg·100 g^{-1})	0.025	0.05-0.23	0.20-0.57	0.21-0.87	0.23
Saponins (mg·100 g^{-1})	0.021-0.04	0.02-0.04	0.018-0.03	0.019-0.03	0.02
Oxalates (mg·100 g^{-1})	0.18	0.04-0.05	0.15-0.86	0.16-0.46	0.17
Terpenoids (mg·100 g^{-1})	0.15	0.04	0.12	0.14	0.15
Trypsin inhibitor (mg·100 g^{-1})	0.338	0.046	0.136	0.204	0.261
Glycosids (mg·100 g^{-1})	0.02-0.046	0.012	0.032	0.035	0.038
Flavonoids (mg·100 g^{-1})	0.47-1.82	0.13-0.66	0.36-0.78	0.39-0.82	0.41
Alkaloids (mg·100 g^{-1})	0.59-1.05	0.20	0.35	0.37	0.40

microcarpum seeds contain calcium, magnesium, iron, sodium, phosphorus and potassium with values ranging respectively from 0.185; 0.022; 0.01; 0.0125 and 0.15 g·100 g^{-1} to 0.35; 0.24; 0.031; 0.275 and 1.836 g·100 g^{-1} (Anhwange et al., 2004; Uhegbu et al., 2009; Amandikwa et al., 2017; Michael et al., 2019). The magnesium content of *D. microcarpum* seeds (0.24 g·100 g^{-1}) is significantly higher than that of corn or oats (0.125 g·100 g^{-1}) (Diop et al., 2010). Similarly, the calcium content (0.35 g·100 g^{-1}) is higher than that of milk (0.125 g·100 g^{-1}) (Diop et al., 2010). The iron content is of importance, 0.031 g·100 g^{-1}, considering the minimum nutritional intakes recommended by FAO/WHO which are 0.009 g·day^{-1} for men to 0.027 g·day^{-1} for women (Alais & Linden, 1991). With regard to vitamins in *D. microcarpum* seeds, little work has been done. Nevertheless, Michael et al. (2019), reported vitamin A (986.3 to 5364.1 IU·100 g^{-1}), vitamin B1 (0.18-0.36 mg·100 g^{-1}), vitamin B3 (0.09-0.29 mg·100 g^{-1}, vitamin B6 (0.04-0.21 mg·100 g^{-1}), vitamin C (9.32-28.05 mg·100 g^{-1}) and vitamin D (0.25-0.42 mg·100 g^{-1}).

Detarium microcarpum seeds contain some anti-nutrients that can be removed or inactivated by different processing methods. Anhwange et al. (2004), Uhegbu et al. (2009), Amandikwa et al. (2017), Peace & Adekunle (2018) and Michael et al. (2019) investigated the anti-nutrients in *D. microcarpum* seeds and found that they contain a trypsin inhibitor (0.338-0.46 mg·100 g^{-1}), phytic acid (0.025-0.87 mg·100 g^{-1}), tannins (0.67-0.74 mg·100 g^{-1}), saponins (0.04-0.4 mg·100 g^{-1}), oxalates (0.04-0.86 mg·100 g^{-1}), terpenoids (0.04-0.15 mg·100 g^{-1}), glycosids (0.12-0.25 mg·100 g^{-1}), flavonoids (0.13-1.82 mg·100 g^{-1}) and alkaloids (0.2-1.05 mg·100 g^{-1}). Amandikwa et al. (2017), Peace et al. (2018) and Michael et al. (2019) investigated the effects of some processing methods on the anti-nutrients composition of *D. microcarpum* seeds and found that roasting, soaking and boiling treatments reduced the anti-nutrients concentration in *D. microcarpum* kernels significantly. However, dehulling did not lead to significant decreases. Moreover, fermentation reduced the anti-nutrients contents of *D. microcarpum* seeds (Michael et al., 2019). Akpata & Miachi (2001), Owuamanam et al. (2016), Amandikwa et al. (2017) and Peace & Adekunle (2018) have found the following functional and pasting properties: bulk density (0.51-0.92 g·cm^{-3}), water absorption capacity (3.47-11.73 ml·g^{-1}), oil absorption capacity (0.73-3.13 ml·g^{-1}), solubility (2.02-3.01%), emulsion activity (4.25-4.40%), emulsion stability (3.44-3.54%), foaming capacity (8.70-8.75 cm^3) and foaming stability (7.0-9.30 cm^3). According to Uzomah & Odusanya (2011), these functional and pasting properties of *D. microcarpum* seeds are due to their richness in hydrocolloids (water-soluble non-starch polysaccharides and proteins), mainly xyloglucans (59.8 g·100 g^{-1}). Thanks to these hydrocolloids, the flour obtained from the seeds of *D. microcarpum* shows promise as thickening and gelling agent.

2.3. Effect of processing methods on *D. microcarpum* seeds nutritional and functional properties

The effects of different processing methods of seeds of *D. microcarpum* such as: roasting, boiling, soaking and fermentation on chemical and nutritional characteristics of the flours obtained were reported, a summarizing table being included (**Table 2**). According to Michael et al. (2019), the minimum values of water content (6.8%) are obtained with roasting of the seeds, on the other hand the highest values are obtained with soaking (15.3%). In terms of proteins and carbohydrates, the variations are not very noticeable between the different processing methods, but there is a difference with raw seeds (Michael et al., 2019). Regarding lipids, the values of raw seeds and fermented seeds are similar, on the other hand those of roasted, boiled and soaked seeds are different. The maximum values are between 7.6-8.0% in the first case and 16-23% in the second case. An increase in vitamins is observed in soaked and fermented seeds compared to raw seeds. Roasting the seeds dramatically reduces anti-nutrient levels compared to all other processing methods. For seeds of *D. microcarpum*, roasting would be the best method of removing anti-nutritional compounds (Amandikwa et al., 2017; Michael et al., 2019).

Peace & Adekunle (2018) and Michael et al. (2019) found that seed processing methods improve their functional and pasting properties. Indeed, among all the functional and pasting properties, it is only at the level of the apparent density that the raw seed recorded a higher value than the transformed seeds: 0.92 g·cm^{-3} for the raw seed against 0.78 g·cm^{-3} for those fermented (Akpata & Miachi, 2001; Uzomah & Odusanya, 2011; Peace & Adekunle, 2018; Michael et al., 2019). For water absorption, oil absorption and foaming capacities, roasted seeds have the highest values (**Table 3**).

Table 3. Effect of processing methods on techno-functional and pasting properties of *Detarium microcarpum* seeds flour — *Effet des méthodes de transformation sur les propriétés techno-fonctionnelles de la farine de graines de* Detarium microcarpum (Akpata & Miachi, 2001; Uzomah & Odusanya, 2011; Igbabul & Idikwu, 2012; Amandikwa et al., 2017; Peace et al., 2018; Michael et al., 2019).

Functional and pasting properties	Raw	Roasted or toasted	Boiled	Soaked	Fermented
Bulk density (g·cm^{-3})	0.86-0.92	0.62-0.72	0.53-0.70	0.51-0.67	0.67-0.78
Water absorption capacity (ml·g^{-1})	4.9-5.05	5.47-11.73	3.47-10.28	5.47-10.53	4.6-5.40
Oil absorption capacity (ml·g^{-1})	0.73-0.75	1.35-3.13	0.97-2.45	1.42-2.20	0.92-1.72
Foaming capacity (cm^3)	8.7-8.75	8.11	8.56	9.3	4.33-7.71
Swelling power (g·g^{-1})	3.7	4.72	3.42	4.05	not found

2.4. Utilization of *Detarium microcarpum* pulp and seed in food products

Beverages. The first products one lean towards when it comes to fruit are drinks. The pulp and seed of *D. microcarpum* make no exception to this rule. Indeed, among the works studied, several used the pulp or the seed in the production of drinks. Mariod et al. (2009) used the pulp to produce juice and jams in Sudan. To produce juice, they took the powder from the pulp of *D. microcarpum* and added water, sugar and citric acid (**Table 4**), obtaining a juice concentrated at 56% of total soluble solid. They also produced jam from the pulp of *D. microcarpum*, by adding water, sucrose, and pectin. The sensory properties of the jam and juice obtained were evaluated by panelists, the two products being accepted and appreciated for their color, smell, taste and texture. These products based on *D. microcarpum* pulp were preferred over control samples which are products already found on the market in Sudan. However, apart from the work of Mariod et al. (2009), who used the pulp of *D. microcarpum* to produce juice and jam, we did not find any other works that used the pulp of *D. microcarpum* for the production of other food products. Nevertheless, the seed of *D. microcarpum* has been used in the production of several food products, mainly as a stabilizer. *Detarium microcarpum* seed powder has been used as a stabilizer in pineapple jam, mango and orange juices (Onweluzo et al., 1999). These different juices and jam were stabilized for two months at room temperature (26 °C ± 2) with the gum of the seed of *D. microcarpum* and pectin, the products being highly appreciated by the evaluators.

Sauces. Powder from the seed of *D. microcarpum* has been used either as a stabilizer in tomato sauce (Onweluzo et al., 1999) or as a thickener in traditional sauces in southeastern Nigeria (Omokhua et al., 2013). Onweluzo et al. (1999) extracted the gum from the seed of *D. microcarpum*, adding 10 $g \cdot l^{-1}$ on tomato puree for stabilizing purposes (**Table 4**). This sauce was much appreciated even after two months of conservation in glass bottle maintained at room temperature (26 °C ± 2). For soup (traditional sauce from South-East Nigeria), Omokhua et al. (2013) observed an improvement in palatability and flavor compared to traditional sauces without the addition of powder from the seed of *D. microcarpum*.

Pastry products. The gum extracted from the seed of *D. microcarpum* was already used as stabilizer in white bread, raw beef burger and ice cream. Onweluzo et al. (1999) used 0.5% *D. microcarpum* gum in the white bread preparation and obtained a product very appreciated for the crumb and the texture; however, the firmness values of the crumb were lower than that of control bread. After five days of storage, the bread with 0.5% *D. microcarpum* gum, Onweluzo et al. (1999) observed an improvement in the water retention of the bread which even tended to firm up. To use *D. microcarpum* gum as a stabilizer in raw beef burger, Onweluzo et al. (2004) experimented four formulations (0.25; 0.5; 0.75 and 1% of *D. microcarpum* gum). All used ratios improved the quality and stability of the product; however, it was concluded to use *D. microcarpum* gum at a maximum of 0.75% in the production of the raw beef burger, for better quality and good economic return. Alakali et al. (2009) used 0.3 to 0.7% *D. microcarpum* gum as a stabilizer in ice cream, observing that the higher the gum concentration of *D. microcarpum*, the better the quality attributes of the ice cream. Alakali et al. (2009) concluded that the use at 0.7% concentration of *D. microcarpum* gum was the best alternative to replace sodium carboxylmethyl-cellulose (CMC) in ice cream.

3. CONCLUSIONS

This review shows that the reported values of macronutrients, minerals, vitamins, anti-nutrients, functional and pasting properties of *D. microcarpum* pulp and seeds vary considerably. These variations may be due to the quality of the samples (mixing of samples, or samples obtained on the markets or samples from different trees), origin of samples, age of samples and treatment before analysis, analytical methods used, storage conditions, treatment method, genetic variation, soil structure and chemical composition. Food composition can be greatly influenced by environment such as type of soil, soil fertility, water or intensity of sunlight. Indeed, Diop et al. (2010) characterized *Detarium* fruits from six different zones of Senegal and observed variations in the results obtained caused by the variability of the raw material, including habitat, maturity and storage conditions of samples. Furthermore, the investigated literature shows that the analyzed samples were selected and handled differently. For instance, some researchers purchased their *D. microcarpum* fruits or seeds from local markets, *e.g.* Akpata & Miachi (2001), Uhegbu et al. (2009) and Owuamanam et al. (2016). Authors who bought *D. microcarpum* seeds from the market mostly found the highest values. For example, the highest values of proteins of seeds have been evaluated between 34.48 and 37.1% by Akpata & Miachi (2001) and Anhwange et al. (2004), who bought the seeds at the market; lowest values (8.8-17.70%) were found by Amandikwa et al. (2017), Peace & Adekunle (2018) and Michael et al., (2019), who collected the seeds in the field. It was also observed that researches published in the last ten years reported the lowest values intervals

Table 4. The different utilizations of *Detarium microcarpum* pulp and seed in food products — *Les différentes utilisations de la pulpe et des graines de* Detarium microcarpum *dans les produits alimentaires.*

Products	*Detarium* - raw material characteristics	Product composition / Ratio of ingredients	Brief conclusion	Reference
Beverages				
Detarium fruit concentrated juice	Dried powder of fruit pulp	*Detarium microcarpum* fruit pulp powder (1 kg), water, sugar, citric acid (0.3-0.5%)	Concentrated juice reached 56% of total soluble solids. Jam and concentrated juice produced were significantly preferred by panelists for their color, odor, taste, texture and overall acceptability to the control samples.	Mariod et al., 2009
Detarium fruit jam		*Detarium microcarpum* fruit pulp powder (1 kg), water (1:1; w/w), sucrose (540 g), pectin (50 g)		
Mango ready to serve beverage	Dried seed powder use as stabilizer	Mango pulp having a total soluble solid of 17° Brix and 9 $g \cdot l^{-1}$ acid, (1.5, 3.0 and 4.5 $g \cdot l^{-1}$) *D. microcarpum* gum extracted from seed flour, 1.5, 3.0 and 4.5 $g \cdot l^{-1}$ pectin (150 grade), sugar (86 $g \cdot l^{-1}$), citric acid (1 $g \cdot l^{-1}$) and water (810 $g \cdot l^{-1}$)	Mango and orange beverages containing 1.5 $g \cdot l^{-1}$ *D. microcarpum* gum, orange squash containing 10 $g \cdot l^{-1}$ *D. microcarpum* gum and pineapple jam containing 1.4 $g \cdot l^{-1}$ *D. microcarpum* gum and 5.6 $g \cdot l^{-1}$ pectin were highly acceptable and had good storage stability during 2 months at ambient storage.	Onweluzo et al., 1999
Orange ready to serve beverage		Orange juice, 1.5, 3.0 and 4.5 $g \cdot l^{-1}$ *D. microcarpum* gum extracted from seed flour, 1.5, 3.0 and 4.5 $g \cdot l^{-1}$ pectin (150 grade)		
Orange squash		250 $g \cdot kg^{-1}$ orange juice, 12 $g \cdot kg^{-1}$ citric acid, 700 $mg \cdot kg^{-1}$ sulphur dioxide, 1.5, 3.0 and 4.5 $g \cdot l^{-1}$ *D. microcarpum* gum extracted from seed flour, 1.5, 3.0 and 4.5 $g \cdot l^{-1}$ pectin (150 grade)		
Pineapple jam		Pineapple juice (450 $g \cdot kg^{-1}$), sugar (550 $g \cdot kg^{-1}$), preservative (200 $mg \cdot kg^{-1}$), citric acid (2.1 $g \cdot kg^{-1}$), *D. microcarpum* gum extracted from seed flour (0, 0.14, 0.35, 0.42 $g \cdot 100\ g^{-1}$) and pectin (0.7, 0.56, 0.35, 0.28 $g \cdot 100\ g^{-1}$)		
Sauces				
Tomato sauce	Dried seed powder use as stabilizer	Tomato juice (10 kg), sugar (0.75 kg), spices, salt (0.110 kg), *D. microcarpum* gum (10 $g \cdot l^{-1}$ of the juice), pectin (10 $g \cdot l^{-1}$ of the juice), acetic acid (20 ml) and sodium benzoate (4.3 g)	Addition of *D. microcarpum* gum to tomato sauce had no significant effect on the color and appearance of the product. Appreciable increase in consistency was observed in tomato sauce containing *D. microcarpum* gum after 2 months.	Onweluzo et al., 1999

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Table 4 (continued). The different utilizations of *Detarium microcarpum* pulp and seed in food products — *Les différentes utilisations de la pulpe et des graines de* Detarium microcarpum *dans les produits alimentaires*.

Products	***Detarium*** **- raw material characteristics**	**Product composition / Ratio of ingredients**	**Brief conclusion**	**Reference**
Sauces				
Soup	Dried seed powder use as soup thickener	Dried seed powder, red palm oil, traditional local soup of southeastern states of Nigeria	Improves the palatability and flavor of soup	Omokhua et al., 2013
Pastry products				
White bread	Dried seed powder	White wheat flour-gum blends were prepared to contain 0.0, 0.1, 0.25 and 0.5% *D. microcarpum* gum, malt (0.5 g), compressed yeast (2 g), fat (3 g), salt (1.5 g) and sugar (6 g)	At all levels of incorporation, there were increases in water absorption of the dough. Doughs containing gums had higher mixing tolerance index than the control. The 0.5% *D. microcarpum* gum substituted bread had a significantly higher sensory score for crumb grain, texture but lower crumb firmness than the control. Textural analysis after 5 days storage revealed that *D. microcarpum* gum improved moisture retention properties of the bread and reduced crumb firming tendency.	Onweluzo et al., 1999
Raw beef burger	Dried seed powder use as stabilizer	0.25, 0.5, 0.75, and 1.0% *D. microcarpum* gum. Burgers formulated to contain 80% lean beef, 10% water, 6.5% bread crumbs, 0.5% sodium tri-polyphosphate, 0.5% polyphosphate, 0.5% potassium sorbate, and 1.0% sodium chloride	*Detarium microcarpum* gum enriched burgers had lower ($p \leq 0.05$) shrinkage and higher WHC than *Mucuna flagellipes* gum and gum tragacanth burgers. *Detarium microcarpum* gum burgers had comparable scores with gum tragacanth burgers in all the sensory attributes tested. Polysaccharide gums from *D. microcarpum* seeds can serve as effective stabilizers in beef burgers without adverse effect on the quality of the product.	Onweluzo et al., 2004
Ice cream	Seed powder use as stabilizer	60% water, 10% milk solid non fats, 16% sucrose, 12.5% fats, 0.5% emulsifier and *D. microcarpum* gum (0.3 to 0.7%)	Sensory attributes generally improved with increased in concentration of *D. microcarpum* gum. On the basis of the textural and sensory characteristics of the local binders studied, *D. microcarpum* at 0.7% concentration was found to be the best local food binder to replace sodium carboxylmethyl-cellulose (CMC) in ice cream.	Alakali et al., 2009

for the main chemical constituents of *Detarium* fruits. This could be explained by the evolution of technology over the last ten years; more efficient devices have been developed and analysis methods have become more precise. In all the reviewed literature, no studies on the effect of processing methods on the pulp properties of *D. microcarpum* have been encountered.

Overall the current work bring together up-to-date knowledge for understanding that the fruit of *D. microcarpum* contains essential nutrients (carbohydrates, potassium, and iron, and vitamins, seed gum) which justifies the technological and nutritional interest of this wild plant. The work carried out has deeply investigated these properties and explored several areas for valuing both the pulp and the seed in the formulation of food products. Several studies have confirmed that seed processing methods influence nutritional and functional properties. These effects are mostly advantageous because they reduce the level of anti-nutritional compounds and improve certain functional properties. Consequently, boiled and soaked seeds are recommended for use as a thickener for sauces, while roasted seeds are recommended for use in pastry products. The specificity observed through the various studies on the use of the fruit of *D. microcarpum* in food products is that they have mostly extracted the gum from the seed for use. Almost all of the works studied on the use of the seed has always extracted the gum and it is this gum alone that is exploited. This work has not explored the other properties of the seed, so it is limited to the gum. Likewise, the work studied on the use of pulp in food products has also been limited to juices and jam. Similarly, few works have been encountered on the quantities of *D. microcarpum* fruit available, the current quantitative use and the quantities available for a future development in countries where the plant is present. Therefore, a wide range of research possibilities in the context of the formulation of foods containing the pulp or the whole seed of *D. microcarpum* fruit and statistical data on the quantities of the fruit of *D. microcarpum* might be open.

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