Health Benefits of Indigenous Durian

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Durian (*Durio zibethinus* Murr.) is an energy-dense seasonal tropical fruit grown in Southeast Asia. It is one of the most expensive fruits in the region. It has a creamy texture and a sweet-bitter taste. The unique durian flavour is attributable to the presence of fat, sugar, and volatile compounds such as esters and sulphur-containing compounds such as thioacetals, thioesters, and thiolanes, as well as alcohols.

Keywords: durian ; esters ; thioacetals ; thioesters ; volatile compounds ; polyphenols ; propionate

1. Introduction

Durio zibethinus Murr. (family *Bombacaceae*, genus *Durio*) is a seasonal tropical fruit grown in Southeast Asian countries such as Malaysia, Thailand, Indonesia, and the Philippines. There are nine edible *Durio* species, namely, *D. lowianus, D. graveolens Becc*., *D. kutejensis* Becc., *D. oxleyanus* Griff., *D. testudinarum* Becc., *D. grandiflorus* (Mast.) *Kosterm*. *ET Soeg., D. dulcis* Becc., *Durio sp*., and also *D. zibethinus* [1]. However, only *Durio zibethinus* species have been extensively grown and harvested [2]. In Malaysia, a few varieties have been recommended for commercial planting such as D24 (local name: *Bukit Merah*), D99 (local name: *Kop Kecil*), and D145 (local name: *Beserah*). In Thailand, durian species were registered based on local names such as *Monthong, Kradum*, and *Puang Manee*. There are similar varieties between Malaysian and Thailand but with different name as follows: D123 and *Chanee*, D158 and *Kan Yao*, and D169 and *Monthong* [3]. Similar to Thailand, durian varieties in Indonesia are registered based on their local names, such as *Pelangi Atururi, Salisun, Nangan, Matahari*, and *Sitokong* [1][4].

The durian fruit shape varies from globose, ovoid, obovoid, or oblong with pericarp colour ranging from green to brownish [1] (Figure 1). The colour of edible aril varies from one variety to the others and fall in between the following: yellow, white, golden-yellow or red [5]. It is eaten raw and has a short shelf-life, from two to five days [5][6]. Fully ripened durian fruit has a unique taste and aroma, and is dubbed “king of fruits” in Malaysia, Thailand, and Singapore. The unique taste and aroma is attributed to the presence of volatile compounds (esters, aldehydes, sulphurs, alcohols, and ketones) [6][7].

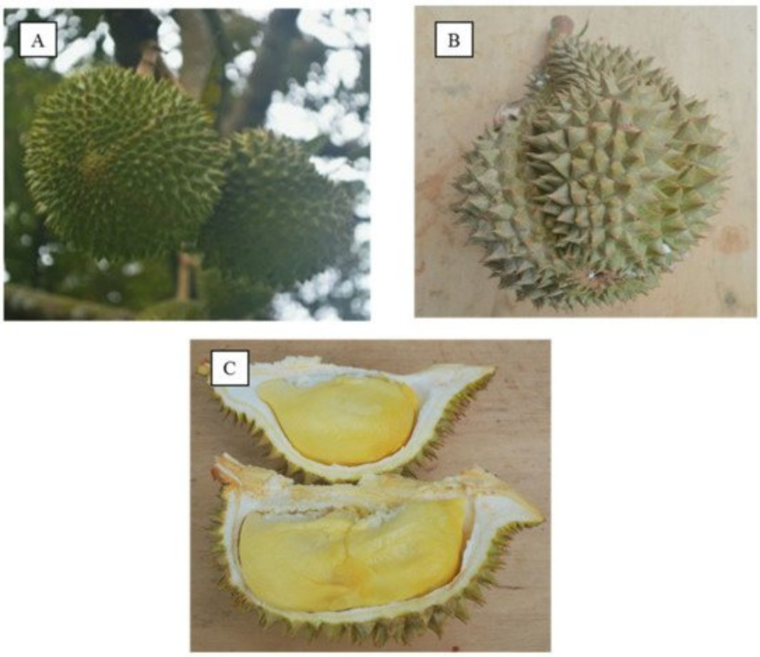

Figure 1. (**A**) Durian tree with fruit. (**B**) Durian fruit with its spiny rind. (**C**) Durian aril (flesh).

Hundreds of volatile compounds have been identified in Malaysian, Thailand, and Indonesian durian varieties such as esters (ethyl propanoate, methyl-2-methylbutanoate, propyl propanoate), sulphur compounds (diethyl disulphide, diethyl trisulphide and ethanethiol), thioacetals (1-(methylthio)-propane), thioesters (1-(methylthio)-ethane), thiolanes (3,5-dimethyl-1,2,4-trithiolane isomers), and alcohol (ethanol) [6][7]. However, the bioactivity of these compounds has not yet been thoroughly explored. A study by Alhabeeb et al. (2014) showed that 10 g/day inulin propionate ester (a synthetic propionate) releases large amounts of propionate in the colon. This subsequently increases perceived satiety (increased satiety and fullness, decreased desire to eat) [8]. Chambers et al. (2015) showed that the same propionate ester (400 mmol/L) increased peptide YY (PYY) and glucagon-like peptide 1 (GLP-1) in primary cultured human colonic cells. This study also showed that 10 g/day of inulin-propionate ester reduced energy intake (14%) compared with the control (inulin) [9].

Durian is also rich in polyphenols such as flavonoids (flavanones, flavonols, flavones, flavanols, anthocyanins), phenolic acids (cinnamic acid and hydroxybenzoic acid), tannins, and other bioactive components such as carotenoids and ascorbic acid [10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25]. Current epidemiological studies have suggested that polyphenols decrease the risk of chronic diseases (e.g., cardiovascular diseases, cancers and diabetes) [26][27][28][29][30]. However, polyphenols might act synergistically with other phytochemicals [26]. However, currently, there are limited studies exploring the health benefits of bioactive components in durian.

2. Nutritional Composition of Different Durian Varieties

The energy content of durian is in the range of 84–185 kcal per 100 g fresh weight (FW) (Table 1) [6][18][19]. This range is somewhat similar to that of the United States Department of Agriculture (USDA), Malaysian, and Indonesian food composition databases [20][21][22]. Durian aril of the Thailand variety of *Kradum* showed the highest energy content at 185 kcal compared with other durian varieties [6][12][13]. Indonesian variety of *Hejo* showed the lowest energy content at 84 kcal per 100 g FW of durian aril [6]. The higher and lower energy contents are attributed to the difference in carbohydrate content. The carbohydrate content varies between different durian varieties in the range between 15.65 to 34.65 g per 100 g FW [6][12][13]. The range of carbohydrate content is similar to that of USDA, Malaysian and Indonesian food composition data, at 27.09 g, 27.90 g, and 28.00 g per 100 g FW, respectively [31][32][33]. The energy content of durian is the highest compared with other tropical fruits such as mango, jackfruit, papaya, and pineapple [31].

Table 1. Nutritional composition of durian aril (flesh) of different durian varieties (g per 100 g fresh weight).

Durian Variety	Indonesian Variety				Thailand Variety				Unknown Variety [31]	Unknown Variety [32]	Unkno Variety [33]
	Ajimah	*Hejo*	*Matahari*	*Sukarno*	*Monthong*	*Chanee*	*Kradum*	*Kobtakam*			
Nutrients											
Energy (kcal) [6] * [31][32][33]	151	84	163	134	134–162	145	185	145	147	153	134
Carbohydrate (g) [6] * [12][13][31][32][33]	28.90	15.65	34.65	27.30	21.70–27.10	20.13	29.15	21.15	27.09	27.90	28.0
Protein (g) [6] * [12][13][31][32][33]	2.36	1.76	2.33	2.13	1.40–2.33	3.10	3.50	2.86	1.47	2.70	2.50
Fat (g) [6] * [12][13][31][32][33]	2.92	1.59	1.69	1.86	3.10–5.39	4.48	4.67	4.40	5.33	3.40	3.00

* For [6], energy was calculated by Atwater factor (1 g protein = 4 kcal, 1 g carbohydrate = 4 kcal, 1 g fat = 9 kcal) [34].

Protein content of different durian varieties is in the range of 1.40 to 3.50 g per 100 g FW [6][12][13]. This range is similar to that of USDA, Malaysian, and Indonesian food composition data, at 1.47 g, 2.70 g, and 2.50 g per 100 g fresh weight (FW), respectively [31][32][33]. Durian contains a high amount of fat and is in the range of 1.59 to 5.39 g per 100 g FW, a figure comparable to the data from USDA, Malaysian, and Indonesian food composition databases at 5.33 g, 3.40 g, and

3.00 g of fat per 100 g FW, respectively [6][12][13][31][32][33]. The fat content of durian is somewhat comparable to one-third of ripe olives [31]. Total sugar of Malaysian, Thailand, and Indonesian durian varieties is in the range of 7.52 to 16.90 g, 14.83 to 19.97 g, and 3.10 to 14.05 g per 100 g FW, respectively (Table 2). The Thailand variety of *Kradum* showed the highest total sugar, at 19.97 g per 100 g FW. Sucrose was the predominant sugar in durian, with 5.57 to 17.89 g per 100 FW, followed by glucose, fructose, and maltose. However, the Malaysian variety of D24 contains higher amounts of fructose than glucose.

Table 2. Sugar composition of different durian varieties (g per 100 g fresh weight).

Sugars	Fructose [13][35][36]	Glucose [13][35][36]	Sucrose [13][35][36]	Maltose [13][35]	Total Sugar [6] * [13][35][36]
Malaysian Variety					
Durian Kampung	1.60	2.21	12.58	0.51	16.90
D2	1.66	2.51	7.70	NA	11.87
D24	0.76	0.73	6.03	NA	7.52
MDUR78	1.82	2.77	8.02	NA	12.61
D101	1.29	1.97	5.57	NA	8.83
Chuk	1.28	1.87	10.65	NA	13.80
Thailand Variety					
Monthong	0.15	0.74	13.69	0.25	14.83
Chanee	0.26	0.58	15.71	0.00	16.55
Kradum	0.33	0.71	17.89	1.04	19.97
Kobtakam	0.10	0.45	17.30	0.26	18.11
Indonesian Variety					
Ajimah	NA	NA	NA	NA	14.05
Hejo	NA	NA	NA	NA	3.10
Matahari	NA	NA	NA	NA	8.14
Sukarno	NA	NA	NA	NA	8.12

* Total sugar is the sum of each individual sugar except for [6], NA, not available.

Table 3 shows fatty acid compositions of different durian varieties. Thailand durian varieties showed higher monounsaturated fatty acids (MUFA) than saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA), with exception of *Monthong*. Palmitic acid (16:0) was the major SFA, in the range of 84.57 to 1696.00 mg per 100 g FW, while oleic acid (18:1) was the major MUFA found in the matured or fully ripened durian (64.89 to 2343.30 mg per 100 g FW). However, each study used a different technique for fatty acid analysis. Gas chromatography was used by Charoenkiatkul et al. (2015) while high pressure liquid chromatography was used by Haruenkit et al. (2010) [13][14]. Both MUFA and SFA might be involved in various metabolic pathways, including the regulation of transcription factors and the expression of multiple genes related to inflammatory processes [37][38][39].

Table 3. Fatty acid (FA) composition of different durian varieties (mg per 100 g fresh weight).

Thailand Variety		*Monthong*	*Chanee*	*Kradum*	*Kobtakam*
Fatty Acid Name	Nomenclature	Fatty Acids Composition			
Decanoic (Capric) [14]	C 10:0	0.11–0.19	NA	NA	NA
Dodecanoic (Lauric) [13]	C 12:0	3.07	16.00	16.68	9.63
Tetradecanoic (Myristic) [13][14]	C 14:0	1.50–30.70	64.00	41.70	32.10
Hexadecanoic (Palmitic) [13][14]	C 16:0	84.57–1473.60	1696.00	1626.30	1508.70
cis-9-Hexadecenoic (Palmitoleic) [13]	C 16:1	122.80	192.00	125.10	160.50
Octadecanoic (Stearic) [13][14]	C 18:0	3.48–61.40	64.00	83.40	96.30
cis-9-Octadecenoic (Oleic) [13][14]	C 18:1 *n*-9	64.89–1074.50	1952.00	2376.90	2343.30
cis-9,12-Octadecadienoic (Linoleic) [13][14]	C 18:2 *n*-6	10.78–184.20	128.00	125.10	160.50
cis-6,9,12-Octadecatrienoic (γ-Linolenic) [13]	C 18:3 *n*-6	184.20	384.00	208.50	96.30
Eicosanoic (arachidic) [14]	C 20:0	0.58	NA	NA	NA
Saturated FA (SFA) [14]		1565.70	1824.00	1751.40	1669.20
Monounsaturated FA (MUFA) [14]		1228.00	2144.00	2543.70	2503.80
Polyunsaturated FA (PUFA) [14]		337.70	480.00	375.30	256.80

NA, not available.

Table 4 shows the mineral compositions of ripe Thailand durian. Durian is high in potassium in the range from 70.00 to 601.00 mg per 100 g FW [11][13][14][31][32][33]. This is comparable to potassium-rich fruit such as banana, with the value of 358.00 mg per 100 g FW [31]. Phosphorus, magnesium, and sodium are in the range of 25.79 to 44.00, 19.28 to 30.00, and 1.00 to 40.00 mg per 100 g FW, respectively. Durian is also a source of iron, copper, and zinc with the range of 0.18 to 1.90, 0.12 to 0.27 and 0.15 to 0.45 mg per 100 g FW, respectively. The Thailand variety of *Chanee* showed the highest level of iron, zinc and potassium among the studied durian [12][19][20][21][22][29]. Durian also contains vitamin A, different types of vitamin B, and vitamin E [13][14][15][31][32][33].

Table 4. Mineral and vitamin contents of different durian varieties.

Durian Variety	Thailand Variety				Malaysian Variety	Unknown Variety [31]	Unknown Variety [32]	Unknown Variety [33]
	Monthong	*Chanee*	*Kradum*	*Kobkatam*	Unknown [15]			
Macrominerals (mg per 100 g fresh weight)								
Calcium [13][14][31][32][33]	4.298–6.134	5.44	3.75	3.21	NA	6.00	40.00	7.00
Phosphorus [13][14][31][32][33]	25.79–33.59	32.96	36.70	37.56	NA	39.00	44.00	44.00
Sodium [13][14][31][32][33]	6.14–15.66	11.84	19.60	21.51	NA	2.00	40.00	1.00
Potassium [13][14][31][32][33]	377.00–489.42	539.20	439.52	438.17	NA	436.00	70.00	601.00
Magnesium [13][14][31][32][33]	19.28–24.87	23.36	23.35	22.79	NA	30.00	NA	NA
Microminerals (mg per 100 g fresh weight)								
Iron [13][14][31][32][33]	0.18–0.23	0.45	0.33	0.36	NA	0.43	1.90	1.30
Copper [13][14][31][32][33]	0.13–0.15	0.27	0.23	0.17	NA	NA	NA	0.12
Manganese [14]	0.23–0.26	NA	NA	NA	NA	NA	NA	NA
Zinc [13][14][31][33]	0.15–0.21	0.45	0.37	0.32	NA	0.28	NA	0.30
Vitamins (μg per 100 g fresh weight)								
A (RAE)	NA	NA	NA	NA	NA	2.00	NA	NA
B_1/Thiamine	NA	NA	NA	NA	NA	374.00	100.00	100.00
B_2/Riboflavin	NA	NA	NA	NA	NA	200.00	100.00	100.00
B_3/Niacin	NA	NA	NA	NA	NA	1074.00	NA	13650.00
B_6/Pyridoxine	NA	NA	NA	NA	NA	316.00	NA	NA
E/Tocopherol or Tocotrienol (μg per 100 g fresh weight)								
α-tocopherol	NA	NA	NA	NA	3774.00	NA	NA	NA
γ-tocopherol	NA	NA	NA	NA	1013.00	NA	NA	NA

Durian Variety	Thailand Variety				Malaysian Variety	Unknown Variety [31]	Unknown Variety [32]	Unknown Variety [33]
	Monthong	*Chanee*	*Kradum*	*Kobkatam*	Unknown [15]			
δ-tocopherol	NA	NA	NA	NA	11.00	NA	NA	NA
δ-tocotrienol	NA	NA	NA	NA	1.00	NA	NA	NA

NA, not available; RAE, retinol activity equivalent.

Table 5 shows soluble, insoluble, and total dietary fibres in Thailand durian varieties. However, there are limited data available for Indonesian and Malaysian varieties. The total dietary fibre is in the range from 1.20 to 3.39 g per 100 g FW for Thailand *Monthong* variety. However, it must be noted that different analyses were used between studies. Soluble dietary fibre varied from 0.74 g (*Puang Manee)* to 1.40 g (*Monthong*) per 100 g FW while insoluble dietary fibre is in the range from 0.60 g (*Kan Yao)* to 2.44 g (*Chanee*) per 100 g FW [10][12][16].

Table 5. Soluble, insoluble, and total dietary fibre in different durian variety (g per 100 g fresh weight).

Type of Fibre	Soluble [10][12][16]	Insoluble [10][12][16]	Total Dietary Fibre [10][11][12][13][16][31][32][33]
		Thailand Variety	
Monthong	0.40–1.40	0.80–1.92	1.20–3.39
Chanee	1.14	2.44	2.91–3.58
Kradum	0.77	1.64	2.41–3.17
Kan Yao	1.01	0.60	1.61
Puang Manee	0.74	1.95	2.69
Kobtakam	NA	NA	2.41
Unknown variety	NA	NA	3.80
Unknown variety	NA	NA	0.90
Unknown variety	NA	NA	3.50

NA, not available.

3. Health Benefits of Durian

Durian is rich in macronutrients (sugars and fat) and micronutrients (potassium), dietary fibres, and bioactive and volatile compounds. An intake of one serving size of durian aril (155 g) contributes to 130 to 253 kcal and is equivalent to one large pear and four small apples without skin, respectively [6][31][32][33]. Durian is energy-dense due to sugar and fat content and hence, might contribute to daily energy intake and will also increase postprandial blood glucose.

3.1. Effects of Durian on Blood Glucose

Durian is high in sugar, but supplementation of 5% freeze-dried *Monthong* (Thailand variety) in 1% cholesterol-enriched diets in rats for 30 days did not raise the plasma glucose level compared with control diet [40]. In humans, Robert et al. (2008) showed that durian had the lowest glycaemic index (GI = 49) compared with watermelon (GI = 55), papaya (GI = 58), and pineapple (GI = 90) [41]. The low GI value for durian might be due to the presence of fibre and fat. Fibre slows digestion in the digestive tract and will slow down the conversion of the carbohydrate to glucose, thus lower the GI of food [42]. Fat does not have a direct effect on blood glucose response, but it may influence glycaemic response indirectly by delaying gastric emptying, and thus slowing the rate of glucose absorption [43].

Durian is rich in potassium and is similar to potassium-rich fruit, i.e., banana [31]. A meta-analysis study showed that there was a linear dose-response between low serum potassium and risk of type 2 diabetes mellitus [44]. Chatterjee et al. (2017) demonstrated that potassium chloride supplementation reduced the worsening effect of fasting glucose in African-Americans compared with placebo [45]. Collectively, the evidence has shown that potassium content in durian might play a role in the regulation of blood glucose. The effect of durian on blood glucose has not been thoroughly explored both in animal and human studies, and hence, warrants further investigation. Potassium might play a role in glucose homeostasis but might also have negative implications in certain conditions. For instance, those with chronic kidney disease (CKD), diabetes mellitus (DM), and heart failure (HF) or on pharmacological therapies may develop hyperkalaemia [46].

3.2. Cholesterol-Lowering Properties of Durian

Anti-atherosclerotic properties of durian aril have been reported in experimental rat models [10][11][20][22][47][40]. Previous in vitro and in vivo studies investigated the health benefits of durian (*Monthong* variety) on lipid profiles [10][11][22]. Haruenkit et al. (2007) showed that rats fed with durian significantly ($p < 0.05$) reduced postprandial plasma total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) with 14.9% and 21.6%, respectively, compared with control group [10]. Gorinstein et al. (2011) showed a reduction in the levels of plasma TC (12.1%), LDL-C (13.3%), and triglycerides (TG) (14.1%) compared with the control group [11]. The results were consistent when tested with other durian from Thailand varieties (*Chanee* and *Kan Yao*) compared with control. Leontowicz et al. (2011) showed that rats supplemented with ripe durian had significantly lowered TG (26.3%), but not significant in TC (4.8%) and LDL-C (6.3%). Histological analysis demonstrated that ripe durian protected the liver and aorta from exogenous cholesterol loading and protected the intimal surface area of the aorta [20]. Durian also demonstrated the ability to hinder postprandial plasma lipids compared with snake fruit and mangosteen [10][11][22]. Previous studies have showed that propionate (0.6 mmol/L) inhibited fatty acid and cholesterol synthesis in isolated rat hepatocytes [48]. In our review, three different propionate esters were identified, i.e., ethyl propionate, methyl propionate and propyl propionate. These esters could be a potent inhibitor for free fatty acids and cholesterol synthesis but this warrants further investigations. However, these esters are highly volatile and could be easily vaporized during sample processing and storage [48].

3.3. Anti-Proliferative Activity

The polyphenol and flavonoid contents of durian are in the range of 21.44 to 374.30 mg GAE and 1.90 to 93.90 mg CE per 100 g FW. The mechanisms of action of polyphenols strongly relates to their antioxidant activity. Polyphenols are known to decrease the level of reactive oxygen species in the human body [49]. The phenolic groups present in the polyphenol structure can accept an electron to form relatively stable phenoxyl radicals, thereby disrupting chain oxidation reactions in cellular components [50]. On the other hand, polyphenols could induce apoptosis and inhibit cancer growth [51][52][53][54]. There are many studies pointing out an essential role of polyphenolic compounds as derived from vegetables, fruits, or herbs in the regulation of epigenetic modifications, resulting in the antiproliferative protection [55]. Jayakumar and Kanthimathi studied the anti-proliferative activity of durian using a breast cancer cell line (MCF-7). This study showed that durian fruit can be considered as potential sources of polyphenols with protective effects against nitric oxide-induced proliferation of MCF-7 cells, an oestrogen receptor-positive human breast cancer cell line [56]. At a concentration of 600 µg/mL, durian fruit extracts inhibited MCF-7 cell growth by 40%. However, an in vivo study is needed to confirm this effect.

3.4. Probiotic Effects

Durian aril is rich in sugar with total sugar content between 3.10 to 19.97 g per 100 g FW. The moisture content of durian aril is 56.1 g to 69.3 g per 100 g FW and pH between 6.9 to 7.6 [5][13][31]. These could be an optimum condition for bacteria fermentation. Durian aril is fermented after being left at room temperature for a few days and turns sour and watery. In Malaysia, underutilised durian aril is fermented (spontaneous and uncontrolled) to a product known as *Tempoyak* [57]. *Tempoyak* is widely used as seasoning in cooking. According to Leisner et al. (2001) lactic acid bacteria (LAB) are the predominant microorganisms in *Tempoyak* [58]. The LAB microorganisms were identified as *Lactobacillus plantarum*. However, other species including *Lactobacillus fersantum, Lactobacillus corynebacterium, Lactobacillus brevis, Lactobacillus mali, Lactobacillus fermentum, Lactobacillus durianis, Lactobacillus casei, Lactobacillus collinoides, Lactobacillus paracasei* and *Lactobacillus fructivorans* were also reported in *Tempoyak* [58][59][60][61]. Khalil et al. (2018) and Ahmad et al. (2018) recently demonstrated the potential of *Tempoyak* as a source of probiotics. The study by Khalil et al. (2018) isolated seven *Lactobacillus* strains that belonged to five different species of the genus *Lactobacillus*, including one *Lactobacillus fermentum* (DUR18), three *Lactobacillus plantarum* (DUR2, DUR5, DUR8), one *Lactobacillus reutri* (DUR12), one *Lactobacillus crispatus* (DUR4), and one *Lactobacillus pentosus* (DUR20) from *Tempoyak*. These strains were able to produce exopolysaccharide (EPS) and had great potency to withstand the extreme conditions, either at low pH 3.0, in 0.3% bile salts or in in vitro model of gastrointestinal conditions [60]. EPS has the prebiotic potential to positively affect the gastrointestinal (GIT) microbiome and may reduce cholesterol [61]. Ahmad et al. (2018) isolated *Lactobacillus plantarum* from *Tempoyak* and showed good probiotic properties including acid and bile salt tolerance, antioxidative, antiproliferative effects, and remarkable adhesion on colon adenocarcinoma cell line (HT-29 cell lines) [62].

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