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Assessment of Functional Properties Flours from Seven Local Varieties of Cassava (*Manihot esculenta* Crantz) Consumed in Côte d'Ivoire

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A B S T R A C T

The present research was carried out to study some functional properties of seven local flours (Agbablé3, Bonoua2, Bondoukou4, Boufouh3, Boufouh4, Soclopouopo3, Totoba2) cassava (*Manihot esculenta* Crantz) varieties. The functional properties (hydrated density, apparent density, porosity, water absorption capacity, oil absorption capacity, hydrophil-lipophil ratio, water solubility index, emulsion capacity, foam capacity, wettability, gelatinization temperature, blue value index) of were evaluated. The Boufouh3 variety flour had highest hydrated density (0.83±0.02 g/ml), emulsion capacity (1.86±0.81%), wettability (32.66±2.87s). Boufouh4 variety flour had the highest values in apparent density (0.62±0.01), foam capacity (21.42±1.5 %) and blue value index (63.3±0.01 % DO/mg). Agbablé3 variety flour had highest water absorption capacity (97.28±6.23%). Soclopouopo3 variety flour had the highest values in porosity (51.25±1.86%) and Hydrophil-lipophlil ratio (0.97±0.02). Totoba2 had highest water solubility index (27.56±0.35%). Bondoukou4 variety flour had the highest values in gelatinization temperature (72±0.82°C) and oil absorption capacity (108.15±2.25%). The functional properties of flours studied show many differences and few similarities. Flours varieties Boufouh3 and Boufouh4 have higher values in functional properties compared to others.

Introduction

Cassava (*Manihot esculenta* Crantz), native to Latin America (Hillocks *et al.*, 2002a), is growing in nearly 100 countries (all developing), including more than 30 African countries (Djilemo, 2007). Cassava (*Manihot esculenta* Crantz) is a widely grown tuber and staple food for millions of people in the tropics of Africa, Latin America and Asia. At the global level, in terms of annual production, it is the fifth most important food crop after maize, rice, wheat and potatoes (FAOSTAT, 2011). Cassava is a major root crop and an important staple food for more than 500 million people in developing countries (Djoulde, 2005; Falade, 2010). Cassava cultivation is traditionally produced in small family farms and mainly processed and consumed at the household level. Cassava is a cheap, easily available and reliable source of carbohydrates, especially in the case of food shortages. This drought-resistant crop has always played an important role in preventing famine in West, East and Southern Africa (Nweke, 2005).

World production is estimated at 278.7 million tonnes, of which Nigeria is the world's largest producer with 54.832 million tonnes, or 20.3% of world production (FAOSTAT, 2014).

Cassava (*Manihot esculenta* Crantz) is one of the most important sources of commercial starch production in tropical and subtropical countries (Moorthy, 2004).

Cassava has played and continues to play a major role in efforts to alleviate food crises because of its efficient food production, available all year round, which is extremely tolerant of stressful conditions and to peasant agriculture and agriculture food system in Africa (Maziya -Dixon *et al.,* 2007).

Cassava is highly perishable and the presence of cyanogenic compounds in its roots requires treatment just after harvest (Westby, 2002). One of the best ways to preserve them is to turn them into flour and / or starch (Perez *et al.*, 2005). Thus, cassava flour is an ingredient increasingly used in the manufacture of a large number of commercial food products. Indeed, it is used in bakery and baking where it goes into the preparation of cookies, cakes, ice cream and ice cream cones, flakes, pasta, puff pastry, etc. (Akoroda, 2007).

In some countries, such as Benin and Nigeria, people have quickly recognized the need to process cassava into byproducts (Cossettes, Chikwangue, Fufu, Gari, Attieke, Tapioca (Bokanga, 2001) whose gain is generally higher than fresh roots

In Côte d'Ivoire, several meals (placali, kongondé, bédèkouma, gari, etc.) were obtained from cassava roots (Kakou, 2000, Amani *et al.*, 2007). Despite its great importance, cassava is subject to several problems such as diseases, low productivity and low nutritional value. Many studies have been undertaken to solve these problems.

Thus, new varieties of cassava were obtained in Côte d'Ivoire by the CNRA (National Center for Agronomic Research) after several crosses between two original varieties V4 (IAC, white color) and V23 (Anango agba, yellow color). They had higher root yields and were more resistant to diseases and pests than existing local varieties (N'zué *et al.*, 2001). However, for these new varieties, food composition data that are very important in the area of nutrition and health (Sodjinou, 2006) were unknown. The properties (biochemical, physico-chemical, functional) on these new varieties remain unknown although consumed by populations.

The aim of this study is to determine some functional properties of flours from seven varieties (Bonoua2, Boufouh3, Boufouh4, Bondoukou4, Agbablé3, Soclopouopo3, Totoba2) of cassava in order to be able to popularize and promoted their use in various fields.

Materials and Methods

Plant material

The roots of seven new improved cassava (Agbablé3, Bonoua2, Boufouh3, Boufouh4, Bondoukou4, Soclopouopo3, Totoba2) of twelve month sold were harvested from

CNRA (National Center for Agronomic Research) experimental plot (Bouake, Côte d'Ivoire).Roots were put in coolers to preserve their fresh state, they were transported to the Laboratory of Biochemistry and Food Technology of University of Nangui Abrogoua (Abidjan, Côte d'Ivoire) where study was conducted.

Flour sample preparation

Fresh roots were peeled manually and cut into small pieces with a inox knife. The pieces obtained were washed and dried in an oven at 45 °C for 48 hours. Dry pieceswere crushed and sieved to obtain the raw cassava flour that has been used for various analyzes.

Methods

Functional properties analysis

Water absorption capacity and solubility index

The water absorption capacity (WAC) and the water solubility index (WSI) of the flours are determined according to the methods of Phillips and al. (1988) and Anderson and al. (1969).

Two (2) g of flours (M0) are dissolved in 50 ml of distilled water contained in a centrifuge tube. This mixture is stirred for 30 minutes with a stirrer and then kept in a water bath at 37 ° C. for 30 minutes. It is then centrifuged at 5000 rpm for 15 minutes. The pellet obtained (M2) is weighed and then dried at 105 ° C to a constant mass (M1). WAC and WSI are calculated from the following relationships:

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

$$\text{WSI}\ (\%) = \frac{\text{M0} - \text{M1}}{\text{M0}}\ \text{x } 100$$

Oil absorption capacity

The oil absorption capacity (OAC) of the flours is determined according to the method of Sosulski (1962). One (1) g (M0) of flours is dissolved in 10 ml of oil. The mixture is stirred for 30 minutes at room temperature using a mechanical stirrer and then centrifuged at 4500 rpm for 10 minutes. The pellet recovered is weighed (M1). The oil absorption capacity (OAC) is calculated from the following formula:

$$\text{OAC}\ (\%) = \frac{\text{M1} - \text{M0}}{\text{M0}}\ \text{x } 100$$

Apparent density and porosity

The apparent density (AD) of the flours is determined according to the method of Narayana Rao and Narasinga (1994). Fifty (50) grams of flour or starch (ME) are placed in a 100 ml graduated cylinder.

The volume (V_0) of this sample is noted after a good leveling with a spatula (without beating the specimen on the bench). Then, the specimen is gently tapped on the bench until a constant volume noted Vt.

$$\text{AD}\ (\frac{\text{g}}{\text{ml}}) = \frac{\text{ME}}{Vt}\ \text{P}(\%) = \frac{\text{V0} - \text{Vt}}{\text{V0}}\text{x}100$$

Hydrated density

A mass of 0.5 g of flours is carefully added to prevent adhesion to the walls of the test tube with 5 ml of distilled water contained in a graduated 10 ml test tube.

The difference between the volume of the water before (V0) and after (Vt) the addition of the sample is marked as the volume of water displaced in ml. The result is expressed in grams of flour or starch per ml of displaced water.

$$HD\ (g/ml) = \frac{V0 - Vt}{V0} \times 100$$

Hydrophilic-lipophilic ratio

The hydrophilic-lipophilic ratio (R) as defined by Njintang and al. (2001), is calculated by comparing the water absorption capacity with the oil absorption capacity. It is a report that evaluates the comparative affinity of flours for water and for oil.

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

Emulsion capacity

The emulsion capacity (EC) of the flours is determined according to the method of Beuchat (1977) slightly modified. Two (2) g of flours (ME) are dispersed in 50 ml of distilled water contained in an Erlenmeyer flask. The mixture is homogenized with a magnetic stirrer for 20 minutes. The suspension is transferred to a centrifuge tube and then ten (10) ml of oil (V0, density 0.88 g/ml) are added thereto. This mixture is stirred continuously for 5 minutes and then heated in a water bath for 15 minutes at 85 ° C. The tube is removed, then cooled to room temperature (25 ° C) for 10 min and centrifuged at 4500 rpm until the volume of oil (V1) separated from the emulsion (V2) becomes constant. The results are expressed as a percentage of emulsified oil per gram of flour used.

$$EC\ (\%) = \frac{V2}{ME} \times 100$$

Foam capacity (FC) and foam stability (FS)

The foam capacity (FC) and foam stability (FS) of flours are determined according to the method of Coffman and Garcia (1977).Three (3) grams of flours are transferred into a graduated 50 ml test tube previously dried in an oven at 50 ° C. The flour is leveled and the volume noted (V0). Then, thirty (30) ml of distilled water is added to the sample to facilitate the dispersion of the flour in the test tube and the volume is also noted (volume before homogenization); then the test tube is vigorously stirred by hand and the new volume is read on the test piece (volume after homogenization).

The volume of the foam obtained is calculated by making the difference between the volume after homogenization and the volume before homogenization. The test piece is allowed to rest on the bench until the foam collapses (Mariod *et al.*, 2010) and at each time interval (every 10 min), the volume of the foam is determined. The foaming capacity (FC) and the stability of the foam (SF) of the flours are calculated from the following formulas:

$$FC\ (\%) = \frac{\text{Vol after homogenization} - \text{Vol before homogenization}}{\text{Vol before homogenization}}$$

$$FS\ (\%) = \frac{\text{Volume of the foam at time t}}{\text{Volume initial of the foam}} \times 100$$

Wettability

The wettability of the flours is determined according to the technique of Onwuka (2005). One (1) gram of flour is placed in a graduated 25 ml test tube having a diameter of 1 cm. A finger is placed on the opening of the specimen (to avoid pouring the sample by reversing it).

The finger closing the specimen is placed at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger is removed and the sample is poured into the beaker. Wettability is the time needed for the sample to become completely wet.

Dispersibility

The dispersibility (D) of the flours is determined according to the method described by (Mora-Escobedo *et al.,* 2009). The dispersibility of the flour is defined as the difference between the total volume (V0) of the particles just after the stirring manually and the volume (Vt) of the deposited particles recorded at time t min.

$$D\ (\%) = \frac{V0 - Vt}{V0} \times 100$$

Point of gelatinization

The method of Narayana Rao and Narasinya (1982) is used to determine the gelling temperature. Ten (10) g of flour sample is dispersed in a 250 ml beaker containing 100 ml of distilled water. A thermometer is blocked on a stand with its bulb immersed in the suspension under a magnetic stirrer heater. Heating and stirring continued until frost was obtained and the corresponding temperature was recorded.

Statistical analysis

All analyses were performed in triplicates. Results were expressed by means of ± SD. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the functional properties of cassava flours. Means were separated according to Duncan's multiple range analysis (p#0.05), with the help of the software Statistica (StatSoft Inc, Tulsa USA Headquarters) (Duncan, 1955).

Results and Discussion

The functional properties of flours from seven local cassava varieties are presented in Table 1. The functional properties differ significantly ($p < 0.05$) one variety to another. Functional properties or characteristics are the intrinsic physico-chemical properties that reflect the complex interaction between the composition, structure, confirmation and physicochemical properties of protein and other food components and the nature of environment in which these are associated and measured (Kinsella,1976). Functional properties of flours play important role in the manufacturing of products.

Flour density is important for determining packaging and handling requirements according to (Ezeocha *et al.*, 2011).

Hydrated density values of seven cassava varieties ranged between 0.68 ± 0.02 and 0.83 ± 0.01 g/ml. Totoba2 variety had the lowest value (0.68 ± 0.02g/ml) and the varieties Boufouh3 and Agbablé3 the highest values (0.83 ± 0.01 g/ml).These values are higher than the taro meal (0.42 and 0.45 g/ml) obtained by Himeda (2012).

Apparent density values ranged between 0.49±0.01 and 0.62±0.01g/ml. Boufouh4 variety had the highest value (0.62±0.01g/ml) and Bonoua2 variety the lowest value (0.49 ± 0.00g/ml). Apparent density values of seven flours of cassava are lower than yam (*Dioscorea bulbifera*) apparent density value (0.72±0.02 g/ml) according to Achy *et al.*, (2017), wheat flour (0.71 g/ml) found by Akubor (2007). The high apparent density increases the absorption capacity of the powder particles, which enhances their ability to disperse (Udensi and Okaka, 2000; Ekwu *et al.*, 2005).

Porosity values varied from 40.95±1.35 to 51.25 ± 1.86%. Soclopouopo3 variety flour had the highest porosity (51.25 ± 1.86%) while Totoba2 variety the lowest (40.95±1.35%). The varieties Agbablé3, Soclopouopo3 and Totoba2 hadporosities values not differ significantly ($p < 0.05$).

According to Onuegbu *et al.,* (2001), high water absorption capacity is needed in baked foods such as bread. The water absorption capacity varies with size, shape, presence of protein, carbohydrate and lipids, pH and salts (Ezeocha *et al.,* 2011).

Water absorption capacity (WAC) is a critical function of protein in various food products like soups, dough and baked products (Adeyeye and Aye, 1998). Water binding capacity is affected by the presence of minerals such as phosphorus in starch, where high phosphorus starches have high water binding capacities (Zuluaga *et al.,* 2007).

The ability of flour to absorb water is a very important property of all flours in food preparations, in swelling and consistency of products as well as in cooking applications (Niba *et al.,* 2001). The water absorption capacity (WAC) of flours from the seven varieties of cassava varied from 75.57±6.40 (Agbablé3) to 97.28 ± 6.23% (Totoba2). The WAC of seven flours are lower than Voandzou flour WAC (199.26 to 239.75%) reported by Diallo *et al.,* (2015), yam (*Dioscorea*sp) flour WAC (182.3 ± 4.1 to 390.7 ± 4.4%) (Dumont, 1995). This water absorption capacity plays an important role in the choice of flours for thickening sauces and soups (Kaur *et al.,* 2013).

The solubility index in water seven flours ranged between 10.13 ± 2.15 (Boufouh 3) and 27.56 ± 0.35% (Totoba 2). Thus, those of the yam *Dioscorea dumetorum* (12.0 ± 0.4 to 15.0 ± 0.1%) (Mbome, 1991) are included among those of the seven varieties.

Oil absorption capacity (OAC) is attributed mainly to the physical entrapment of oils. It is an indication of the rate at which the protein binds to fat in food formulations (Singh *et al.,* 2005).

Dinor oil absorption capacity of flours varied from 80.45±3.2 (Soclopouopo3) to 108.15± 2.25% (Bondoukou4). The lower oil absorption capacity of cassava flours could be due to low hydrophobic proteins which show superior binding of lipids (Adeleke and Odedeji, 2010).The variation of the absorption capacity of oils (OAC) in flours is associated with the presence of non-polar chains (Njintang *et al.,* 2003).

Fig.1 Dispersibility of flours from seven varieties of cassava

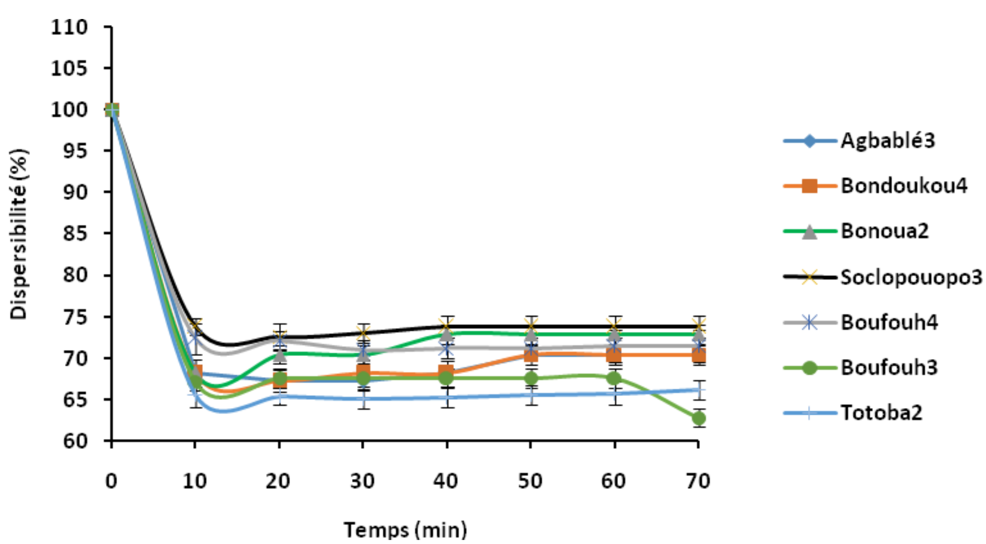

Table.1 Functional properties flours from seven local varieties of cassava (*Manihot esculenta* Crantz)

Properties	Cassava varieties						
	Agbablé3	Bondou kou4	Bonoua2	Soclo-pouopo3	Boufouh4	Boufouh3	Totoba2
HD (g/ml)	0,83±0,01^{a}	0,76±0,02^{bc}	0,74±0,01^{c}	0,81±0,02^{ab}	0,82±0,01^{a}	0,83±0,02^{ab}	0,68±0,01^{d}
AD (g ml)	0,50±0,01^{a}	0,58±0,01^{c}	0,49±0,00^{a}	0,50±0,00^{a}	0,62±0,01^{d}	0,57±0,01^{b}	0,50±0,02^{a}
P (%)	44,60±0,85^{b}	42,65±0,22^{ab}	51,16±1,19^{d}	51,25±1,86^{d}	47,85±0,71^{c}	47,85±0,79^{c}	40,95±1,35^{a}
WAC (%)	97,28±6,23^{d}	95,64±4,01^{cd}	87,38±3,95^{bc}	78,53±5,46^{ab}	81,98±2,88^{ab}	91,93±4,45^{cd}	75,57±6,40^{a}
OAC (Dinor) %	106,25±3,85^{c}	108,15±2,25^{b}	98,9±2,1^{b}	80,45±3,2^{d}	85,25±3,75^{a}	100,7±3,80^{b}	88,75±0,95^{a}
HLRD	0,91±0,03^{abc}	0,88±0,02^{ab}	0,88±0,08^{ab}	0,97±0,02^{c}	0,96±0,03^{bc}	0,91±0,04^{abc}	0,85±0,05^{a}
WSI %	18,30±2,86^{b}	19,63±1,23^{b}	12,36±2,19^{a}	13,03±2,0^{a}	2,36±1,01^{c}	10,13±2,15^{a}	27,56±0,35^{d}
EC (%)	1,80±0,16^{c}	1,97±0,17^{g}	1,88±0,24^{f}	1,82±0,00^{d}	1,56±0,16^{a}	1,86±0,81^{e}	1,75±0,04^{b}
(FC) (%)	13,63±1,00^{b}	8,82±0,5^{a}	5,71±0,2^{c}	13,63±0,9^{b}	21,42±1,5^{e}	9,09±0,41^{a}	7,14±0,05^{d}
W (S)	27,0±5,10^{a}	31,50±1,08^{a}	15,18±1,65^{b}	15,33±2,5^{b}	32,0±3,56^{a}	32,66±2,87^{a}	28,33±4,92^{a}
PG (°C)	68±0,47^{b}	72±0,82^{c}	70±0,45^{a}	70±0,81^{a}	70±0,82^{a}	69±0,47^{ab}	70±0,47^{a}

*All results are mean ± standard error for three replicates
*Different alphabets in superscript in each row show significant difference between values

Hydrophilic-lipophilic ratios of seven flours varied from 0.87 ± 0.05 (Totoba 2) and 1.04 ± 0.02 (Soclopouopo3). There is no significant difference between all these varieties. These ratios are less than 1, which clearly shows that cassava flours obtained have a higher affinity for Dinor oil than water.

Emulsion activity and stability (%) Protein being the surface active agents can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Kaushal *et al.*, 2012). The emulsion capacity of flours ranged between 1.56 ± 0.11% (Boufouh4) and 1.86 ± 0.17 % (Boufouh3).

The temperature at which gelatinization of starch take place is known as the gelatinization temperature (Sahay and Singh, 1996). The study revealed that the flour which was higher in starch content took lowest temperature for gelatinization. The gelatinization point of seven flours ranged between 68±0.47 °C (Agbablé) and 72 ± 0.82 °C (Bondoukou4). The Bonoua2, Soclo pouopo3, Boufouh4 and Totoba2 varieties all have the same values (70 °C). The gelatinization point of the flours of 7 varieties of cassava is between 68 and 72°C. According to Amani (2002), the gelatinization temperature of yams florido (75.8°C), kponan (73.5°C) are higher than the seven varieties cassava studied. In addition, the values of cassava Bonouan (70°C), Ouanga (69°C) and Akaman (70°C) flours reported by Zoumenou *et al.*, (1994) are in values obtained in this study.

Foam capacity (FC, %) and Foam stability (FS, %) Foam capacity of protein refers to the amount of interfacial area that can be created by the protein (Fennama, 1996). Foam is a colloidal of many gas bubbles trapped in a liquid or solid. Small air bubbles are surrounded by thin liquid films. Foams are used to improve the texture, consistency and appearance of foods (Akubor, 2007). Flours with high foaming ability could form large air bubbles surrounded by thinner a less flexible protein film. This air bubbles might be easier to collapse and consequently lowered the foam stability (Jitngarmkusol *et al.*, 2008). The foaming capacity of flours ranged between 5.71 ± 0.2 (Bonoua2) and 21.42 ± 1.5% (Boufouh4). There is no significant difference ($p < 0.05$) between varieties

Bondoukou4, Boufouh3 and Agbablé3, Soclopouopo3.

The wettability of seven flours of cassava varied from 15.18±1.65s (Bonoua2) and 32.66± 2.87 s (Boufouh3). Wettability is a function of the ease of dispersion with respect to the displacement in the water of the sample. The sample with lowest wettability time would dissolve in the water more rapidly than samples with higher wettability (Ubbor *et al.,* 2006). The Boufouh3, Boufouh4 and Bondoukou4 varieties have the closest and the highest values, but there is no significant difference ($p < 0.05$) between Totoba2 and Agbablé3 varieties.

Then the flours of these two varieties dissolve more quickly than the other varieties. According to Schuck (2011), a powder is considered wettable if its wettability time is less than 60s and very wettable if it is less than 30s. In addition, the values obtained Bonoua2, Agbablé3, Totoba2 and Soclopouopo3 are less than 30s so the seven flours of cassava are very wettable.

The dispersibility percentage is an indicator of good water absorption capacity of flours and an indicator of good quality of the gel according to Eke-Ejiofor *et al.,* (2014). The dispersibility of flour gives an indication of the suspension of the particles in water (Mora-Escobedo *et al.*, 1991). Kulkarni *et al.*, (1991) reported that dispersibility is associated with fine particle size. The dispersibilities of seven flours from cassava varied from 62.85 (totoba2) to 73.80% (Soclopouopo3). According to Sara *et al.*, (2008) a high value of dispersibility increases the emulsifying and foaming properties of proteins. The values obtained are higher than those of Himeda (2012) on taro flour (29 and 30.56%). The values reported by Eke-Ejiofor *et al.,* (2011), which are 55-66% (local rice) and 50-70% (Caprice rice), are in the range of the seven flours of cassava (Fig. 1).

The apparent and hydrated densities of the flours are all less than 1 with porosities ranged from 40.95 to 51.25%. The seven flours are very wettable with a wettability of less than 30s and absorb more oil than water with hydrophilic-lipophilic ratios less than 1. The emulsifying capacities and foaming properties of the flours are low and due to the low protein content in the flours. These flours have good dispersibility values giving a reconstitution capacity of a fine and consistent dough. As for the gelatinization points of the seven flours are around 70 °C. The functional properties flours of the seven varieties of cassava (*Manihot esculenta* Crantz) studied demonstrate their ability to use in various fields.

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