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Functional, Particle Size and Sorption Isotherm of Cocoyam Cormel Flours

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Abstract: The functional, particle size distribution and sorption kinetics of cocoyam cormels were investigated to reveal their suitability in food systems and storage stability. Four cultivars of cocoyam cormel were harvested processed into flour and the resultant flours investigated for the functional, particle size distribution and sorption isotherm. The *Ede ofe* of the *Colocasia* spp. had highest crude protein content (9.72%), followed by *Ede ocha*, *Xanthosoma* spp, (8.13%) while *Ede cocoindia* had the least, 7.93%. These values are higher than are obtainable in other root crops such as yam or cassava. *Ede uhie* had proportional distribution than the rest of the cultivers. *Ede uhie* had the highest value for viscosity, 0.246cp while *Ede cocoindia* had the least, 0.089 cp. *Ede cocoindia* had the highest water absorption capacity, 2.410g/g, followed by *Ede ofe*, 2.195 g/g while *Ede uhie* scored the least, 2.082 g/g. The bulk density of *Ede ofe* was highest, 0.95 g/cm^3 while *Ede uhie* had the least score, 0.76 g/cm^3. The sorption isotherm study revealed that relative humidity in the neighborhoods of 65-70% would be ideal for storage of the flours in moisture tight package materials. Monolayer values ranged from 0.0367-0.0787 gH_2O/g solid which suggest better storage stability of the flour when store at ambient temperature, 30^{o}C. Going by the data obtained cormel flours from the *Xanthosoma* species can be used as a composite in bread making while their Colocasia counterparts would perform better in emulsion food system.

Key words: Cocoyam cormel, protein content, viscosity, bulk density, equilibrium moisture, monolayer moisture

INTRODUCTION

Cocoyam is regarded as the third most important root crop after yam and cassava in West Africa (Obomegheive *et al*., 1998). It is a staple food for millions of people living in the tropics. Onwueme and Simha (1991) reported that cocoyam cultivars have yield potentials for 37-75 tonnes /hectare and the corms and cormels are rich in minerals, vitamins and digestive starch grains. Despite these nutritional benefits, cocoyam is less valued in areas like Eastern Nigeria where it is produced in abundance (IITA, 1992; FAO, 2006). According to Kordylas (1990) about 30-40 specie of cocoyam have been identified but only 5-6 specie produce edible parts. Two genera of cocoyam are widely cultivated in Africa-these are namely taro (*Colocasia esculenta*) and tannia (*Xanthosoma sagittifolium*). Cocoyam is one of the under exploited tropical plants though with promising quality. However research and development on cocoyam have been meager in Nigeria when compared with other tropical root crops like yam and cassava (Onwuka and Eneh, 1998). Among the reasons advanced for the under utilization of cocoyam is due to the presence of calcium oxalate raphide-the irritant which causes itching effect felt through out the throat when consumed (Purseglove, 1983). Another reason is that cocoyam is prone to pre harvest and post harvest diseases, which reduce storage stability and quality of the tubers (Hahn *et al*., 1987). According to Iwuoha and Kalu (1995) proper cooking eliminates the harsh and sharp irritation in the throat and mouth while the post harvest losses would be obviated by prompt processing of the harvested tubers into cocoyam flour. The present study investigates the physical, chemical and sorption isotherm of flour from selected cormels of cocoyam cultivars. According to Enwere (1998) the cormels of cocoyam are used traditional as soup thickeners. Some skeletal works have been reported on some proximate and functional properties as well as their industrial application (Osisiogwu *et al*., 1974; Olaofe *et al*., 1998). However no work has been done exclusively on the cormels and the utilization of the flour in food formulation and preparation. None also has been reported more especially on their sorption isotherm. The physical, chemical and sorption isotherm provide indexes for food material characterization and storage stability in varying humidity. This work is expected to draw more attention on research and development activity on cocoyam toward provision of food security for people living in the tropics.

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MATERIALS AND METHODS

Sample preparation: Wholesome cocoyam cormels (*Colocasia esculenta cv ede ofe, Colocasia esculenta cv ede cocoindia, Xanthosoma sagitifo litium cv ede ocha* and *Xanthosoma sagittifolium cv edeuhuie)* used in this study were harvested on the month of November, 2008 from an experimental farm at Imo State University Owerri, Nigeria. The cornels were cleaned, peeled and sliced with stainless kitchen knife and washed with tap water. The slices were treated with 20 ppm solution of sodium metabisulphate in water for 20 min. The slices were subsequently treated with hot water for 5 min and then oven dried at 70°C. The dried samples were milled into flour and stored in air-tight containers.

Chemical composition: Moisture content crude protein, fibre, fat, ash and carbohydrate were determined according to AOAC (1990).

Moisture content determination: The moisture cans were washed and dried in the oven and weighed using analytical weighing balance. Five grams of the sample were put into previously weighed moisture can. The sample in the moisture can was put into the oven (Gallenkamp Hot box size 1, air- dried type) at 105°C for 3.0 h. The sample was removed and placed in the desiccators to cool and weighing was carried out afterwards. The sample was reheated and cooled intermittently until constant mass was obtained. The difference in mass as percent moisture was calculated as the % moisture content.

Crude protein determination: The Kjeldahl apparatus was used for the determination of crude protein. One half grams (0.5 g) of each dry sample was weighed and put into a Kjeldahl digestion flask. One tablet of Selenium catalyst was added into each of the flask moistened with distilled water and mixed with 10 ml of concentrated H_2SO_4. The mixture was heated to red-hot temperature under a fume cupboard for 2 h to obtain a clear solution. The digest was transferred quantitatively to 100 ml volume flask and diluted to mark with distilled water. An aliquot of the digest (10 ml) was mixed with equal volume of 45% NaOH solution in a semi-micro kjeldahl distillation apparatus. The mixture was distilled and the distillate collected into 10 ml of 4% boric solution containing 3 drops of mixed indicator (methyl red and bromocressol green). A total of 50 ml distillate was collected and titrated against 0.02N H_2SO_4 solution. A blank experiment was also set involving digestion of all the materials except the sample. The distillation was also carried out on the blank. The titre value of the blank was subtracted from that of the sample and the difference obtained was used to calculate the crude protein.

The percent nitrogen content was calculated as

$$\text{Crude protein (\%)} = \%\ N \times 16.25$$

Crude fibre determination: Two (2 g) grams of each sample were digested with 200 ml of 1.25% H_2SO_4 solution under reflux for 30 min boiling. The digest was allowed to cool and than filtered with Buckner funnel equipped with muslin cloth. The residue was washed thrice with hot water, scooped into a conical flask and digested with 200 ml of 1.25% NaOH solution under reflux for 30 min boiling. The digest was cooled, filtered and washed thrice with distilled water. The residue was drained and scooped into a previously dried and weighed crucible and then put into the oven to dry at 105°C to a constant mass. The dish with its content was reweighed after drying and then placed in the muffle furnace to ash at temperature of 550°C for 3 h. The ash was withdrawn at the end and put in a bell jar and reweighed. The difference in mass of the sample was calculated as crude fibre and expressed as a percent of the initial mass.

Ash determination: Two grams of the sample was weighed into previously cleaned, dried crucible of known mass. The crucible with the content was weighed and the mass recorded. The crucible with the content was placed into a muffle furnace at 550°C for 3 h until the sample turned white and free from carbon. At the end of incineration, the ash substance was withdrawn and cooled in a bell jar and reweighed. The mass of the residual incinerate was calculated as % ash content.

$$\text{Ash}(\%) = \frac{\text{Mass of ash x 100}}{\text{Mass of sample}}$$

Carbohydrate determination: The carbohydrate content was determined by deference that is by deducting the mean values of other parameters that were determined from 100. Therefore

$$\text{Carbohydrate (\%)} = 100 - (\%mc + \%CP + \%fat + \text{crude fibre} + \%Ash)$$

Where:
mc = Moisture content
CP = Crude protein

Physical properties

Particle size: The method of Idowu *et al.* (1996) was used. Test sieves of various apertures (90 μm, 75 μm and 50 μm) were arranged in ascending order and mounted on the test sieve shaker. 20 g of the flour was put in the top sieve and covered with the lid. The shaker was switched on and operated for 30 min after which the sieves were removed and the retained amount was determined by weighing. The percent retention of each

sieve was calculated. Means values were calculated after four determinations.

Viscosity: The brook field synchrolectric viscometer was used to determine the viscosity of slurry made from the flour. Twenty (20) g of the flour was put in 250 ml beaker and 200 ml of tap water added to form slurry. The slurry was heated at 100°C for 15 min to gelatinize. The brook field synchrolectric viscometer was set at zero and 60 rev per minute. The viscosity of the pap was determined when the spindle revolves 60 time/minute.

Blue value index (BVI): The method of Atkins (1982) was followed. Three (3) g of the flour was weighed into 50 ml beaker and 30 ml dispersion made and allowed to stand for 30 min 30°C, which was filtered afterward with whatman (No 42) filter paper. 10ml of the filtrate was measured into 25 ml conical flask and titrated with O.I.N iodine solution using phenophtalein as indicator. The titre value was recorded at the blue colour end point. Percent blue value index was calculated as:

$$BVI\ (\%) = \frac{VD}{VA} \times \frac{Vt}{Mf} \times \frac{N}{100} \times 100$$

Where:
VD = Total volume of dispersion
VA = Volume of aliquot used for filtration
Vt = Titre value
Mf = Mass of flour used
N = Normality of iodine

Water absorption capacity: The method of Abbey and Ibeh (1988) was followed to determine water absorption capacity. One (1) gram of the flour was mixed with tap water in a centrifuge tube and made up to 10 ml dispersion and allowed to rest at room temperature for 30 mins. The sample was centrifuge at 3000 rpm with Heltich model centrifuge. The volume of the supernatant was measured using 10 ml graduated cylinder. The density value 1000 kg/m^3 was assumed and mean water absorption capacity obtained after four determinations in (g/g).

Gelatinization temperature: The method of Narayana and Narasanya-Rao (1982) was adopted with slight modification. Twenty five (25) grams of the flour was dissolved in tap water in a beaker and made up to 100ml dispersion. The dispersion was placed on heating mantle and stirred as heating progresses. The gelling temperature was recorded at the gelling point of the flour in °C.

Bulk density: The method of Milson and Kirk (1980) was followed to determine the bulk density. Fifty (50) grams of the sample was weighed into 100 ml graduated cylinder and the initial volume recorded. The cylinder was tapped repeatedly for 100 times to a constant volume and the final volume recorded. The bulk density was calculated as the mass of the sample divided by the volume at the end of tapping.

Porosity: The porosity was calculated using the values obtained for the case of bulk density: thus

$$Porosity = \frac{Initial\ volume - Final\ volume}{Initial\ volume}$$

Sorption isotherm: The method of Greenspan (1977) was followed; inorganic salt solutions ($LiCl.H_2O$, $MgCl_2.6H_2O$, Na $Br.2H_2O$, $NaNO_3$, NaCl, KCl, BaCl and K_2SO_4) were prepared to create varying humidity (11, 33, 56, 65, 75, 85, 90 and 97%) respectively in desiccators. One gram flour was placed in the desiccator above the saturated solution. Weighing was carried out twelve hourly until a constant weight is achieved, according to Zurith *et al.* (1979).

Monolayer value: The Caurie's (1981) modified Brunauer-Emmett and Teller (BET) (1938) equation was followed for the determination of monolayer adsorption of water at 30°C, expressed as:

$$\frac{a_w}{Xm\,(1-a_w)} = \frac{1}{MoC} + \frac{1}{Xm} \quad (1)$$

Where:
Xm = Equilibrium moisture content at a given water activity
Mo = Monolayer value
C = Constant for a given system

RESULTS AND DISCUSSION

Chemical properties: The crude proteins of the various cultivars were found to differ significantly at $p<0.05$ as shown in Table 1. The *Xanthosoma* spp performed better than the *Colocasia* spp. and *Ede ocha* had the highest while cocoindia had the least crude protein. High protein content is desirable not only on nutritional ground but for the functionality of the flour in food system. Thus, functional properties such as absorption capacity, gelling and rheology are influenced by the type and nature of proteins found in the flour. From this, *Ede ocha* might offer better advantage to processors who may wish to use the flour as composite in bread making.

The carbohydrate value did not differ among the cultivars at $p<0.05$, thus signifying the importance of cocoyam as energy giving food nutrient. According to Srilakshmi (2008) cocoyam contains starch molecules that are not very easily digestibly - Slowly Digestible Starch (SDS) - thus making cocoyam a low glycaemic food. Hence cocoyam has become a favorable food for diabetes (Eneh, 1992).

Table 1: Chemical properties cocoyam cormel flours

	Colocasia esculenta		*Xanthosoma sagittifolium*		
Chemical properties (%)	*Ede cocoindia*	*Ede ofe*	*Ede Uhie*	*Ede ocha*	LSD
Ash	2.00^{a}±1.37	1.38^{a}±0.70	0.63^{a}±0.23	0.68^{a}±0.23	Nil
Fat	0.88^{a}±0.03	0.51^{b}±0.05	0.83^{a}±0.02	0.80^{a}±0.08	0.13
Crude protein	4.64^{c}±0.46	5.08^{b}±0.61	5.69^{c}±0.10	5.70^{a}±1.08	0.27
Moisture content	7.93^{a}±1.33	9.72^{a}±1.41	8.04^{a}±1.20	8.13^{a}±1.44	Nil
Fibre	0.36^{c}±0.02	0.48^{b}±0.07	0.20^{d}±0.82	0.62^{a}±0.52	0.12
Carbohydrate	84.19^{a}±4.2	82.83^{a}±3.7	84.61^{a}±0.1	84.075^{a}±7.5	Nil

Mean ± standard deviation of quadruplet determination on dry weight basis. Means with similar alphabets across the row are not significant different at $p<0.05$

The fibre of *Ede ocha* was highest among the cormel's flour while *Ede uhie* was the least. Fibre plays more important role in human nutrition than its functionality in food system. It contributes to bowl movement and cocoyam has been a health food for people with gastro-intestinal disorders (Onwueme, 1978). With the exception of *Ede ofe*, the rest of the cultivars did no differ in fat content. More over, no significant difference was observed in the ash and moisture content.

Particle size: The particle size of the cormel's flours revealed that majority of the particles was retained on 90 µm sieve signifying that the average size of the flour might be 90 µm or more (Table 2). However the retention on the sieve differed significantly at $p<0.05$ and at 90 µm *Ede ofe* had the highest retention of flour and *Ede ocha* the least. Large particle size might play a much greater role than has been suggested in terms of bonding forces on particulate surfaces which influences functional properties such as water absorption capacity, viscosity and gelling temperature. According to Ayernor (1983) particle size highly correlates with the extent of damaged starch as measured by the blue value index. The suitability of cocoyam flour in infant based products would depend on the smoothness of the reconstituted end product which is directly influence by the particle size.

Physical properties: The result in Table 3 shows that the blue value index as measured did not vary in their means ($p<0.05$) for the flours from the various cultivars. However among the means, *Ede ofe* scored the highest while *Ede cocoindia* had the least. Blue value index is influenced by the degree of damaged starch during milling (Greer and Stewart, 1959).

The viscosity of the cultivars from the *Xanthosoma* spp. were higher than those of their Colocasia counterparts, thus *Ede ocha* had the highest (0.24 cp) while *Ede ofe* had the least. High viscosity flour is required for baking purpose, hence the *Xanthosoma* spp. could be used as composites in bread making rather than the *Colocasia* spp.

The water absorption capacity of the comel's flours differed significantly ($p<0.05$) with *Ede ofe* having the highest value and *Ede ocha* the least. The low water absorption capacity of *Ede ocha* may be associated with large amount of small particles on 50 µm mesh size. Again, it is revealed that large particle size favors high water absorption capacity. Ayernor (1983) stated that the degree of disintegration of the native starch granule influences the water binding ability of starchy system. The ability of the starchy system to incorporate water molecules enables addition of water during food preparation (Akobundu *et al*., 1982). Absorption of water ensures improved handling of flour, maintenance of freshness of baked goods and useful in sausage production.

Ede uhie flour exhibited the highest gelling temperature while *Ede cocoindia* had the least. Low gelling temperature is desirable in terms of energy cost for cooking. Onwueme (1978) associated gelling ability to the percentage of damaged amylose fraction to amylopectin ratio of the starch. Thus *Ede cocoindia* is expected to have high ratio of amylose than amylopectin.

The bulk density and the porosity of the flours were significantly different at $p<0.05$. The *Xanthosoma* spp. scored higher than the *Colocasia* spp. with *Ede uhie* having the highest value and *Ede cocoindia* the least. Porosity is the reverse of bulk density as shown by the result in Table 4. It is possible the particle size of the granules would affect the bulk density. These physical properties are considered during packaging and transportation in the industry (Haung and Clayton, 1987). With the exception of *Ede ofe* the rest of the cultivars did not differ at $p<0.05$ in which the study was conducted for the solid density. Solid density is another important physical property of food that is considered in separation processes such as sedimentation, centrifugation and pneumatic and as well as hydraulic transport of powders and particulate foods (Lewis, 1987). It is also measured in quality assessment of flour.

The equilibrium moisture content of the flours the various cocoyam cultivars is shown in Table 4. At water activity range 0.0-0.30, *Ede cocoindia* absorbed the lowest moisture 0.01-0.02 and *Ede ocha* of the *Xanthosoma* species had the highest moisture 0.03-0.08. These levels of moisture absorption typify monomolecular absorptivity in which water is firmly

Table 2: Particle size distribution of cocoyam cormel flours

	Colocasia esculenta		*Xanthosoma sagittifolium*		
Mesh size	*Ede ofe*	*Ede cocoindia*	*Ede ocha*	*Ede uhie*	LSD
90 µm (%)	94.73^{a}±0.25	87.63^{b}±0.06	81.63^{d}±0.09	81.90^{c}±0.03	0.50
75 µm (%)	1.66^{b}±0.02	1.46^{c}±0.01	3.50^{a}±0.02	1.50^{c}±0.02	0.04
50 µm (%)	2.93^{d}±0.09	2.80^{c}±0.04	17.10^{a}±0.03	12.60^{b}±0.02	0.13

Mean quadruplet samples of cocoyam cormel flours. Means of samples with similar alphabets across the row are not significant at p<0.05

Table 3: Physical properties of cocoyam cormel flours

	Colocasia esculanta		*Xanthosoma sagittifolium*		
Physical properties	*Ede ofe*	*Cocoindia*	*Ede ocha*	*Ede uhie*	LSD
Blue value index	$1.43x10^{-3a}$±$2x10^{-4}$	$1.00^{a}x10^{-3}$±$7x10^{-6}$	$1.02x10^{-3a}$±$5x10^{-6}$	$1.30x10^{-3a}$±$3x10^{-4}$	Nil
Viscosity (cp)	0.153^{c}±$1.0x10^{-3}$	0.089^{d}±$2x10^{-3}$	0.213^{b}±$6x10^{-3}$	0.246^{a}±$2x10^{-3}$	0.01
Bulk density (g/cm^3)	0.95^{a}±0.01	0.80^{b}±$5x10^{-3}$	0.82^{a}±$5x10^{-3}$	0.76^{b}±$5x10^{-3}$	0.09
Porosity (g/cm^3)	0.323^{b}±$8x10^{-3}$	0.318^{b}±$7x10^{-4}$	0.340^{a}±$1.4x10^{-3}$	0.350^{a}±$2.1x10^{-3}$	0.01
Solid density (kg/m^3)	0.244^{b}±3.64	0.280^{a}±0.37	0.281^{a}±0.61	0.284^{a}±0.42	0.10
Water absorption (g/g)	2.195^{b}±$9.6x10^{-4}$	2.410^{a}±$9.6x10^{-4}$	2.178^{c}±$9.6x10^{-4}$	2.082^{d}±$9.6x10^{-4}$	0.00143
Gelling temperature (°C)	63.75^{c}±0.43	69.75^{b}±0.50	65^{c}±0.0	73.8^{b}±1.3	1.28

Mean quadruplet samples of Cocoyam cormel's flours. Means of samples with similar alphabets across the row are not significant at p<0.05

Table 4: Equilibrium moisture content of cocoyam cormel flours (g H_2O/g flour)

Water activity (a_w)	Relative humidity (RH%)	*Ede ofe*	*Cocoindia*	*Ede ocha*	*Ede uhie*
0.11	11	0.02	0.01	0.04	0.03
0.33	33	0.05	0.02	0.07	0.08
0.56	56	0.07	0.05	0.10	0.10
0.65	65	0.10	0.08	0.12	0.13
0.75	75	0.12	0.13	0.18	0.20
0.80	80	0.18	0.19	0.25	0.25
0.90	90	0.26	0.29	0.30	0.33
0.97	97	0.39	0.46	0.41	0.47

bound and is difficult to remove by physical means such as drying. At the water activity range 0.30-0.70, shows a moderate absorption and ede had the highest moisture while *Ede ofe* had the least. This region is referred to as zone of multilayer deposition. However the amount of moisture absorbed by the cultivars is within the range that is safe for safe storage using moderate moisture impervious packaging material. Furthermore the region 0.70-1.0, witnessed steep rise in equilibrium moisture content with a small increase in water activity. Dincer and Esin (1996) reported that the region is characterized by capillary condensation, which may be due to the degree of amorphism reached by the starchy samples. The condition promotes hygroscopy which makes the flour susceptible to caking (Maia and Cal-Vidal, 1994; Nwanekezi, 2007).

The monolayer moisture content ranged from 0.0367-0.0787 gH_2O/g solid with *Ede ocha* having the highest value, 0.0471 gH_2O/g solid as presented in Table 5. Onwuka (2003) listed monolayer range, 0.0320-0.160 g H_2O/g solid for some dry starchy flours. Monolayer moisture content is a measure of sorption ability of starchy food (Kiranoudis *et al*., 1993). It is the minimum amount of water bound to active sites and guaranties the stability of flour during storage (Iglesias and Chirife, 1975). The higher the monolayer values the lower the

Table 5: Monolayer moisture content of cocoyam cormel flours

Cultiver	Monolayer (Mo)gH_2O/g solid
Ede uhie	0.0520
Ede ocha	0.0787
Cocoindia	0.0661
Ede ofe	0.0367

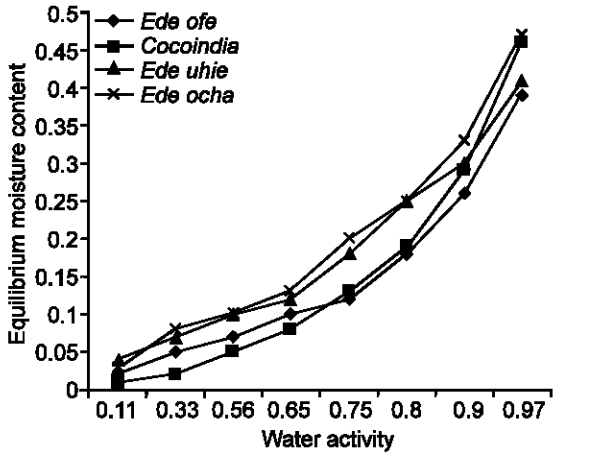

Fig. 1: The sorption isotherm of cocoyam cormel's flours at 30°C

stability of the flour. Thus suggesting that *Ede ocha* provides more binding sites for water molecules and

would least stable in storage, while *Ede ofe* with the lowest monolayer value store for longer time than the rest.

Conclusion: The study has revealed that both cormels of the *Xanthosoma* spp. and the *Colocasia* spp. are comparably richer in crude protein than other tropical root crops. They also contribute quality carbohydrate and dietary fibre to human nutrition. The crude protein and the nature of the carbohydrate play important roles in the functionality of the flour in food system. It is worthy to note that particle sizes of these cultivars influences functional properties such as the water absorption capacity and gelling characteristics of the flours.

The high viscosity of the *Xanthosoma* spp (*Ede uhie* and *Ede ocha*) makes it the preferred choice for baking into bread and different types of cookies. In Nigeria flour millers have been compelled by legislation to incorporate 5% of cassava starch in bread making flours, such commensurate legislation is yet to be extended to cocoyam which is also produced in abundance. Going by this work, it is expected that government should through appropriate legislation compel millers to incorporate cocoyam flour in baking flour.

The results of equilibrium moisture content and monolayer moisture content revealed the drying and storage abilities of the cormel flours. The flours could be stored properly in the environment with relative humidity range 0.60-0.70.

Considering the quality attributes of the cocoyam cormels' flour it is expected that more research work is carried out in the area of storage stability using various packaging materials and at different storage environment and also more comparative study on particle size as it affects the behaviour of the flour in food system is need.

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