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ENGINEERING PROPERTIES OF OKRA (*Abelmoschus esculentus*) SEED

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ABSTRACT

Engineering properties of two Indian okra varieties (Pusa A4 & Punjab-8) were evaluated in laboratory conditions at two moisture regimes i.e. unsoaked and soaked (24 h). The geometric mean diameter and test weight of Punjab-8 and Pusa A4 were respectively found to be 4.69 mm, 4.78 mm and 52.67 g, 63.0 g at 8.51%, 7.37% moisture content on a dry basis (db). Whereas the geometric mean diameter went up to 5.42 mm and 5.76 mm due to increase in moisture content at 73.62%, 67.31% on a dry basis (db) and test weights were increased to 72.33 g and 101.0 g at 73.62% and 67.31% moisture content respectively. The bulk density of the seed was found to decrease with increase in moisture content, it was 0.547g/cm^3 at 8.51% moisture content and 0.489g/cm^3 at 73.62% for Punjab-8 seed variety and a similar trend was observed in Pusa A4. The angle of repose and coefficient of friction on mild steel surface were also increased with increase in moisture content. The angle of repose of the two varieties was 24.24° and 23.37° in unsoaked condition and 33.30^0 and 31.24^0 for the soaked condition. The coefficient of friction was 0.40 and 0.39 for Punjab-8 & Pusa A4 under unsoaked condition and increased to 0.47 and 0.44 in soaked condition. The average value of sphericity and roundness was found to be more in case of PusaA4 as compared to Punjab-8.

Key words: Engineering properties, Okra seeds, Shape, Size, Soaked seed

India is the second largest producer of vegetables in the world after China with the total production of 162.86 million tonnes with an average productivity of 17.3 t/ha. There is abundant production of vegetables like potato, tomato, okra and cucurbits in India (Anon., 2014). It is estimated that per capita consumption of vegetables in India is 230 g/day as against 300 g/day recommended dietary allowance. Therefore, currently, India has a shortage of about 30 million tonnes of vegetables (Vanitha *et al.*, 2013). The inclusion of vegetables in the daily diet is indispensable for the maintenance of good health. To feed the present population of India, there is a need to double the total production of vegetables. Besides this, India has to produce additionally to meet the requirement of the processing industry, exports, and the seed industry.

India is one of the leading okra (*Abelmoschus esculentus*) producing country in the world and total area under cultivation and production of okra is 532.66 thousand hectares and 6346.37 thousand tonnes, respectively (productivity of 11.9 t/ha). This production contributes to 72.9% of world's okra production followed by Nigeria 12.6%, Sudan 3.0% and Iraq 1.8%, etc. (Anon., 2014).

Nutritionally, okra is rich in Ca, K, some other minerals, and in vitamins. The okra root and stem are used for cleaning cane juice in preparation of "*gur*" (jaggery). The dry seed contains 13-22% edible oil and 20-24% protein and oil is used in making of soap, cosmetics and also as *vanaspati* (solidified oil). Whereas, proteins are used for fortified feed preparations. Fresh Okra can be included in the meal and stored for consumption during the off-season (Chadda, 2010).

Sowing time of okra in India varies from region to region and place to place due to geographical diversity. Okra transplanting as well as broadcasting is not preferred and therefore seed is sown directly in the soil by seeding behind the plough or dibbling, or with the seed-drills. Moreover, the okra seed coat is very hard and it does not take up water easily after sowing in the soil, thereby resulting in very poor germination. Thus, for increasing the germination the soaking of okra seed in water for 24 hour is very common practice in India (Yawalkar, 1992; Anon., 2015). The aim of this study was to compare the moisture-dependent engineering properties of okra seed cultivated in India to develop appropriate technologies for its sowing. The development of the technologies will require knowledge of the properties of the okra seed. Besides, dimensions of seed are very important in the design of seed handling machines such as the metering mechanism of planter, sizing, cleaning and grading equipment. Bulk density is the major parameter in the design of hopper, drying and storage systems (Dursun and Dursun, 2005). It is necessary to know the coefficient of friction, angle of repose and shape of seed in the design of hopper. Such basic knowledge of engineering properties of seed is very important not only for the engineers but also for food scientists, plant breeders, processors and other scientists who may find new uses (Mohsenin, 1986).

The physical properties of okra seed as a function of moisture content were evaluated by Sahoo and Shrivastav (2002) who concluded that moisture content had a significant

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effect on engineering properties of seed. Hazbavi (2013) studied moisture dependent physicomechanical properties of Iranian okra (*Ablemoschus esculentus* L.) seed. Gautam *et al*. (2016) studied the engineering properties of pelleted carrot and radish seed, Amin *et al.* (2004) determined the physical properties of seeds at various moisture contents for lentil seed, Konak *et al.* (2002) for chickpea seeds, Ogunjimi *et al*. (2002) for locust bean seed and User *et al.* (2010) for red pepper seed. However, published work on the comparative study of engineering and physical properties of okra seed and their relationship with moisture content is scanty. Thus, the present study had the objective of examining engineering properties of okra.

MATERIALS AND METHODS

Two okra seed varieties, Pusa A4 which was recommended at India level by IARI, Delhi and Punjab-8 recommended for the state of Punjab (Anon., 2015) were employed. The initial moisture content of seeds of the varieties was recorded and then both were soaked in water (temperature 25±2°C) for 24 hours to compare engineering properties under soaked and unsoaked situations in the laboratory (Fig. 1) The moisture content of seeds was determined by the oven-dry method (Ranganna, 1986). The seed samples were placed in an oven to dry at a constant temperature of 72±2°C until constant mass was obtained. The seeds were soaked in water for 24 hours and placed on cotton cloth to let the surface moisture of the seed just dry off before determination of engineering properties of seeds, namely size, shape, mean diameter, thousand seed weight, bulk density, the angle of repose and coefficient of friction. The moisture content of the soaked seeds was 67.31% and 73.62% for Pusa A4 and Punjab-8, respectively.

The average size of seeds was expressed in terms of length, breadth, and thickness and was measured with the help of a digital vernier caliper having least count of 0.01 mm. The dimensions of the randomly selected 30 seeds were measured for each soaked and unsoaked seed. Further, the geometric mean diameter (D_p) of the seeds was calculated using the following relationship (Mohsenin, 1986):

$$D_p = (\sqrt[3]{LWT}) \quad (1)$$

Where, L is the length of seed in mm, W the width of seed in mm and T is the thickness of seed in mm.

The shape of the seed was expressed in terms of sphericity and roundness. Sphericity is a measure of shape character which is compared to the sphere of the same volume. Assuming that the volume of seed is equal to the volume of a triaxial ellipsoid with intercept L, B, and T and that the diameter of the circumscribed sphere is the longest intercept of ellipsoid. Sphericity (ψ) was calculated using the following equation (Sahoo & Srivastava, 2002)

$$\psi = (\sqrt[3]{LWT} / L) \quad (2)$$

The Roundness (R) is a measure of sharpness of the seed corners. The roundness was calculated using the following equation (Mohsenin, 1986).

$$R = (W/L + T/L + T/W)/3 \quad (3)$$

Fig. 1. Soaked and unsoaked seeds of two varieties of okra.

The procedure was repeated for 30 seeds selected randomly and the mean value was taken as a characteristic value of sphericity and roundness of seeds. The observations were recorded both under unsoaked and soaked conditions.

Test weight was determined for ten random samples of 1000 seeds each over an electronic weighing balance having least count of 0.01 g. The bulk density, ratio of the mass of a sample of a seed to its total volume, was determined with a weight per hectolitre tester which was calibrated in g/cm^3 (Mohsenin, 1986). For both soaked and unsoaked condition, the hectolitre tester was filled with the seeds to record the volume. The weight was recorded by using electronic balance. The angle of repose was measured by recording the height and diameter of heap formed by the seeds (Gautam *et al.*, 2016). For the determination of the angle of repose of soaked and unsoaked okra seed, a plastic cylinder (inner diameter 70 mm and height 270 mm) was kept vertically on the horizontal wooden surface and filled with sample. Tapping during filling was done to obtain uniform packing and to minimize wall effect, if any. The cylinder was slowly raised so that whole material could slide down freely to form a heap. The height of the heap (H) and the diameter of the heap (D) were measured with the help of a scale and angle of repose (ϕ) was computed using following relationship (Gautam *et al.*, 2016)

$$\phi = \tan^{-1} (2H/ D) \qquad (4)$$

The coefficient of friction of soaked and unsoaked seeds was determined on mild steel (MS) surface. A table top arrangement comprised of a wooden box (10.5 cm x 10.5 cm x 5 cm), hanging weight pan carrier which was attached to the wooden box with the help of string that passed over a pulley which was fixed on one end of the table (Gautam *et al.*, 2016). The dimensions of the box were so selected as to ensure that the total contact area of okra seed, with a horizontal surface, was large enough to resist the tangential force applied by sliding the whole mass of seed rather than rolling and should be sufficient to be measured easily. The wooden box was positioned on a horizontal MS surface. The weights were put into the pan until the box just started to slide. The total weight (W_1), at this point was noted. The wooden box was filled with okra seed and to eliminate the effect of the rim on the wooden box, the seed box was slightly raised above the floor. Weights were again added to the hanging pan carrier in small amounts until the box filled with seed sample began to just slide on the MS surface. The total weight (W_2) required to slide the box on the selected surface was recorded. The weight of the sample (W) was also noted and the coefficient of friction was computed by the following expression.

$$\mu = (W_2 - W_1) / W \qquad (6)$$

The data were statistically analyzed for each variety in terms of standard deviation and coefficient of variation. Student t-test (assuming unequal variance) was applied to check the significant effect between both varieties as well as between seed treatment.

RESULTS AND DISCUSSION

Size and shape of the seed

Size of the okra seed included length (major dimension), breadth (intermediate dimension) and thickness (minor dimension) parameters of seed. The range, mean, standard deviation and standard error of length, breadth and thickness of both varieties i.e. Punjab-8 and Pusa A4 under soaked and unsoaked conditions are given in Table 1. For Punjab-8 unsoaked seed, the length of seed varied from 4.89-6.67 mm, breadth 3.86-5.13 mm, and the thickness 3.42-4.83 mm having mean values of 5.51, 4.58 and 4.11 mm, respectively at moisture content 8.51% on a dry basis (db). These dimensions were found to have increased with increase in moisture content. As moisture content was increased from 8.51 to 73.62% (db), the mean dimensions such as length breadth and thickness also increased to 6.34, 5.37 and 4.70 mm, respectively with soaking. The range of soaked okra seed for length varied from 5.20-7.30 mm, breadth 4.53-6.10 mm and for thickness it varied from 4.06-5.35 mm. The mean value of the length, breadth, and thickness (minor dimension) was increased by 15%, 17.2%, and 14.3% respectively after soaking in water for 24 hours.

Similarly, for the Pusa A4 unsoaked seed, the length varied from 4.62-6.41 mm, breadth 4.11-5.57 mm and thickness 3.54-5.13 mm at 7.37% (db). The mean values of length, breadth and thickness were 5.46 mm, 4.75 mm and 4.24 mm, respectively (Fig. 2). After soaking for 24 hours, the moisture content of okra seed went up to 67.31% from 7.37% and thus the mean value of length, breadth and thickness were found to have increased to 6.61 mm, 5.70 mm and 5.08 mm. The length, breadth, and thickness were increased by 21%, 20%, and 19.8% respectively after soaking. The increase in the dimension of both seed varieties was observed due to fact that uptake of water by the Punjab-8 and Pusa A4 seeds was 37.32% and 60.30% with respect to initial unsoaked conditions, respectively which caused swelling of seeds. Thus, overall the length, breadth, and thickness dimensions were increased more in case of Pusa-A4 than the Punjab-8 variety. The increase in seed dimensions with increase in moisture content was also observed by Sahoo and Srivastava (2002) for okra seed and Ougt (1998) for white Lupin.

The standard deviation and coefficient of variation of the seed sample were also calculated to assess the variation and uniformity of the seed parameters such as length, breadth, and thickness within the seed sample. For Punjab-8 seed variety, the standard deviation of length, breadth and thickness for unsoaked seed was found to be in the range of 0.34 to 0.45 and for the length, breadth, and thickness the standard deviation was found to be 0.45, 0.37 and 0.34, respectively (Table 1). For the soaked seed, it was found to be in the range of 0.35 to 0.51 (length, breadth, and thickness standard deviation was 0.51, 0.39 and 0.35, respectively). Similarly for the Pusa A4, the standard deviation of the unsoaked seed sample was found to be in the range of 0.32 to 0.46 (length, breadth, and thickness standard deviation was 0.46, 0.32 and 0.42, respectively). In soaked seed the range of standard deviation was from 0.43 to 0.60 and the individually standard deviation for the length, breadth, and thickness was 0.43, 0.60 and 0.43, respectively.

The coefficient of variation of the seed sample for Punjab-8 was found in the range for 7.97% to 8.20% and 7.29% to 8.10% for unsoaked and soaked seed respectively. Whereas, for the Pusa A4, these values ranged from 6.71% to 10.01% and 6.44% to 10.49% for unsoaked and soaked seed sample, respectively. Table 1 depicts the engineering properties of okra seed and Fig. 2 provides comparison of seed dimensions of both varieties under soaked and unsoaked conditions.

The geometric mean diameter was calculated from the above dimensions, namely length, breadth and thickness. The mean value of geometric mean diameter for Punjab-8 variety for unsoaked and soaked condition was found to be 4.69 mm and 5.42 mm with the coefficient of variation of 4.35% and 4.80%, respectively. Whereas, in case of Pusa-A4 variety, it was found to be 4.78 mm and 5.76 mm with the coefficient of variation of 4.67% and 5.49%, respectively for unsoaked and soaked seed (Table 2).

The statistical t-test was applied to the observed data to check the significant difference between the two varieties under two moisture regimes. There was significant difference (at 5% level) observed under soaked conditions for both the varieties (Pusa A4 and Punjab-8) in respect of length, breadth, thickness and geometric mean diameter of seed at 5% level of significance. However, no significant difference was observed between two varieties for length, breadth thickness and geometric mean diameter.

The shape of the seeds was measured in terms of sphericity and roundness. The sphericity was calculated using Eq (2) and it came out to be the mean values 0.85 and 0.85 for Punjab-8 with the coefficient of variation 7.63%

Table 1. Engineering properties - length, breadth, and thickness of okra seed

Variety		Punjab-8		Pusa A-4	
Treatment		Unsoaked	Soaked	Unsoaked	Soaked
Length(mm)	Range(mm)	4.89-6.67	5.20-7.30	4.62-6.41	5.53-7.52
	Mean(mm)	5.51	6.34	5.46	6.61
	SD	0.45	0.51	0.46	0.43
	CV %	8.17	8.10	8.42	6.44
Breadth	Range(mm)	3.86-5.13	4.53-6.10	4.11-5.57	4.52-7.35
	Mean(mm)	4.58	5.37	4.75	5.70
	SD	0.37	0.39	0.32	0.60
	CV %	7.97	7.29	6.71	10.49
Thickness	Range(mm)	3.42-4.83	4.06-5.35	3.54-5.13	4.41-6.10
	Mean(mm)	4.11	4.70	4.24	5.08
	SD	0.34	0.35	0.42	0.43
	CV %	8.20	7.49	10.01	8.53

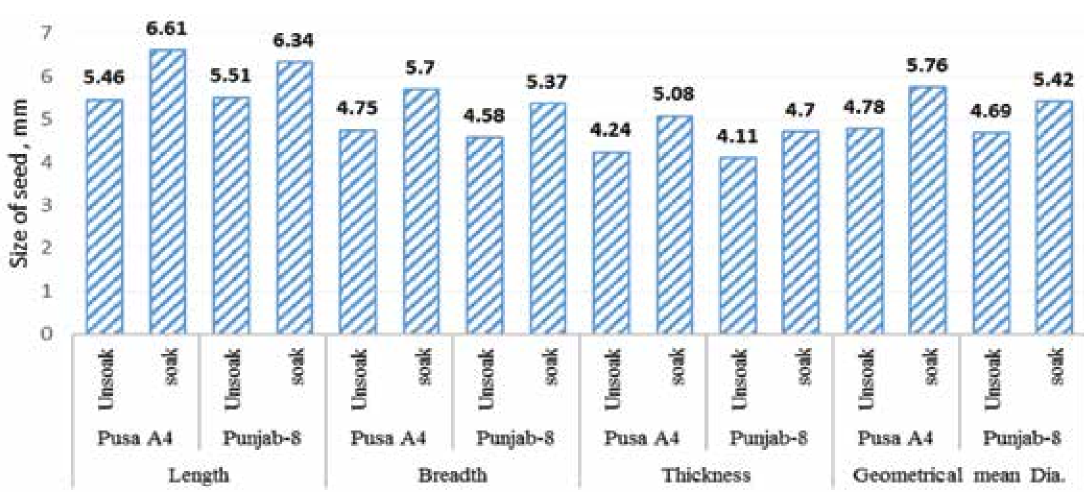

Fig. 2. Comparison of seed dimensions of the two varieties under soaked and unsoaked conditions

and 6.32% for unsoaked and soaked seed, respectively. The higher value of sphericity of seeds showed that seeds were nearly spherical in shape. Whereas, the sphericity of seed for Pusa-A4 was 0.88 and 0.89 with the coefficient of variation of 7.08% and 5.61% for unsoaked and soaked seed conditions, respectively (Table 2). The roundness, measure of sharpness of corners of the okra seed, was found to be 0.83 and 0.86 with a coefficient of variation of 8.49% and 6.70%, respectively in case of Punjab-8 for unsoaked and soaked seed. Similarly, for Pusa-A4 variety, the roundness came out to be 0.85 and 0.85 with a coefficient of variation of 9.56% and 6.46% for the unsoaked and soaked seed conditions, respectively.

There was no significant difference found between the soaked conditions (seed treatment) as well as between varieties (Pusa A4 and Punjab-8) for sphericity and roundness by Student t-test.

Test weight

The average test weight of Pusa A4 (63.0 g) was more than that of Punjab-8 (52.67 g) at their respective initial moisture content. The average value of thousand grain weight was found to be increasing to 52.67 g and 72.33 g with increase in moisture content from 8.51% to 73.62% in case of Punjab-8 seed variety. Whereas, in case of Pusa-A4 variety the test weight was 63 g at 7.37% moisture content and increased to 101.0 g at 67.31% moisture content (Table 3). It was found that the test weight was more in Pusa A4 than Punjab 8 variety. For Punjab-8 seed variety, test weight was increased by 37.3% as moisture content increased from 8.51% to 73.62%. Similarly, for the Pusa A4, it increased by 60.3% with increase in moisture content from 7.37% to 67.31%. There was a significant statistical difference observed with respect to variety and soaking condition. Sahoo and Srivastava (2002), Deshpande *et al.* (1993) and Ougt (1998) also reported an increase in test weight with increase in moisture content for okra, soya bean and while lupin seed respectively.

Angle of repose

The angle of repose was the moisture dependent property. The average value of angle of repose ranged between 23 to 24° in the unsoaked condition of seed for both the varieties. In case of Punjab-8 seeds, the angle of repose was observed at 24.24° and 33.30° for unsoaked (8.51% db) and soaked (73.62%) okra seeds respectively. It showed that angle of repose increased by 37 % with an increase in moisture content from 8.51% to 73.62%. Whereas, in case of Pusa A-4 variety, the angle of repose was 23.37° at 7.37% moisture content and further increased to 31.24° at 67.31% moisture content (Table 3). The value of angle of repose was found it increase significantly with increase in moisture content for both varieties. Increase in the angle of repose was attributed to increase in the cohesiveness of the seeds with an increase in moisture content, hence there was a significant statistical difference observed for both varieties under soaked and unsoaked condition. However, there was no significant difference found for the angle of repose for both variants. The increase in angle of repose with an increase in moisture content was reported by Sahoo and Srivastava (2002) for okra seed and Singh and Goswami (1996) for cumin seeds.

Bulk density

The bulk density of Pusa A4 was (0.589 g/cm^3) higher than Punjab-8 (0.507 g/cm^3) when observed at their initial moisture content. The average value of bulk density was observed to have decreased from 0.507 g/cm^3 to 0.489 g/cm^3 as moisture content increased from 8.51 % to 73.62 % for Punjab-8 seed variety. Whereas, in case of Pusa-A4 it was found to be 0.589 g/cm^3 and 0.546 g/cm^3 at 7.37% and 67.31% moisture content, respectively (Table 3). This was

Table 2. Engineering properties - geometric mean diameter, sphericity, and roundness - of okra seed

Variety		Punjab-8		Pusa A-4	
Treatment		**Unsoaked**	**Soaked**	**Unsoaked**	**Soaked**
Geometric Mean Diameter	Range (mm)	4.10 - 5.01	5.00 - 5.93	4.33 - 5.25	4.90 - 6.51
	Mean (mm)	4.69	5.42	4.78	5.76
	SD	0.20	0.26	0.22	0.32
	CV %	4.35	4.80	4.67	5.49
Sphericity	Range	0.70 - 0.93	0.75 - 0.91	0.73 - 0.95	0.74 - 0.94
	Mean	0.85	0.85	0.88	0.89
	SD	0.07	0.05	0.06	0.05
	CV %	7.63	6.32	7.08	5.61
Roundness	Range	0.68 - 0.92	0.71 - 0.94	0.68 - 0.91	0.70 - 0.93
	Mean	0.83	0.86	0.85	0.85
	SD	0.07	0.06	0.08	0.07
	CV %	8.49	6.70	9.56	6.46

Table 3. Seed test weight, angle of repose, bulk density and coefficient of friction engineering properties of okra seeds

Variety	Punjab-8		Pusa-A4	
Treatment	Unsoaked	Soaked	Unsoaked	Soaked
Moisture content (db) %	8.51	73.62	7.37	67.31
Test weight (g)	52.67	72.33	63.00	101.00
Angle of repose	24.24	33.30	23.37	31.24
Bulk density (g/cm^3)	0.507	0.489	0.589	0.546
Coefficient of friction on mild steel surface	0.40	0.47	0.39	0.44

due to higher rate increase in the volume than of weight of the seed as moisture content increased. There was a significant difference observed for both varieties between soaked and unsoaked condition as well as between both varieties. The decrease in bulk density with increase in moisture content was reported by Sahoo and Srivastava (2002) for okra seed, Deshpande *et al*. (1993) for soybean seeds and Ougt (1998) for white lupin.

Coefficient of friction

The coefficient of friction for Punjab-8 was found to be 0.40 and 0.47 at a moisture content of 8.51% and 73.62%, respectively. Whereas, in the case of Pusa-A4 it was 0.39 and 0.44 at a moisture content of 7.37% and 67.31%, respectively (Table 3). At higher moisture content, seed becomes rough thereby reducing the flowability (sliding), so at higher moisture content coefficient of static friction went up as compared to lower moisture content. There was a significant difference observed for both varieties under soaked and unsoaked condition. However, there was no significant difference found for the coefficient of the fraction between both varieties. The increase in coefficient of friction with an increase in moisture content was also reported by Singh and Goswami (1996) for cumin seeds on MS surface.

The length, breadth, and thickness of both the varieties were found to have increased with increase in moisture content. The geometric mean diameter of Punjab-8 and Pusa A4 was 4.69 mm, 4.78 mm at 8.51% and 7.37% moisture content, respectively and it increased to 5.42 mm and 5.46 mm due to increase in moisture content to 73.62% and 67.31%, respectively. The test weight for Punjab-8 and Pusa A4 was 52.67g, 63.0g at 8.51% and 7.37% moisture content, respectively and increased to 72.33 g and 101.0 g at 73.62% and 67.31% moisture content, respectively. The bulk density of the seed was found to have decreased with increase in moisture content, it was 0.507 g/cm^3 at 8.51% moisture content and went down to 0.489 g/cm^3 at 73.62% for Punjab-8 seed variety and a similar trend was found in Pusa A4. The angle of repose and coefficient of friction also increased with increase in moisture content. The angle of repose for Punjab-8 and Pusa A4 were 24.24^o and 23.37^o in unsoaked condition and 33.30^o and 31.24^o for the soaked condition. The coefficient of friction was 0.40 and 0.39 for Punjab-8 and Pusa A4 under unsoaked condition and increased to 0.47 and 0.44 with soaking. Thus, it can be concluded that varietal differences and soaking practices affect engineering characteristics of okra seeds.

Authors' contribution

Conceptualization of research work and designing of experiments (CMB, HSD, GSM, RK); Execution of field/lab experiments and data collection (CMB, AG); Analysis of data and interpretation (CMB, HSD, AG); Preparation of manuscript (CMB, HSD, GSM, RK).

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