THE INFLUENCE OF THE KNEADER TYPE ON THE RHEOLOGICAL PROPERTIES OF DOUGH

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ABSTRACT

This study presents the comparative analysis of three kneaders with different construction, showing the effects of kneading on dough obtained with the same flour, with the purpose of pinpointing that not only the rheological characteristics of the flour influence the rheological characteristics of dough, but also the type of kneader used in the process of kneading. This has direct influences on the dough, leaving place for open discussions about the differences observed, between the amount of energy introduced into the dough, the quantity of added water, the gas retention of dough pieces and many others.

In the first part of the paper, the kneaders studied in this paper are presented, next to the method used for analysis, in order to explain the differences in the kneading process and real influences over the obtained dough, using the same flour. In the paper, there are analyzed: a horizontal kneader, a planetary one and one with vertical arm. All the three kneaders use intensive kneading, but the level of energy introduced is different. The kneading time varies from 3 minutes for the horizontal kneader, to 6 minutes for the planetary one and 8 minutes for the vertical kneader.

The second part of the paper presents the kneading curves and the ones with the level of introduced energy obtained during tests. In the comparative analysis between the three diagrams can be observed different developments of dough, projected in the drawn curves which pinpoint the direct influence of the type of kneader on the processes like: stability, softening, gluten network development, etc.

In the final part of the paper, it is analyzed the influence of changing the speed at the kneading arm over dough properties, development of kneading curves, different energy levels introduced in the dough and changes in the final product.

Considering the fact that for all the tests was used the same recipe with the same flour but the final products are different, this paper wishes to pinpoint the necessity of another rheological analysis which is made during the kneading process and adapted to every type of kneader, analysis which can be realized with the device and method developed.

Key words: kneader, dough, rheological analysis, kneading process, water absorption.

INTRODUCTION

The kneading process is the crucial operation in breadmaking industry, by which, the flour, water and the rest of ingredients, under the action of mechanical work, are transformed into coherent dough [5,9,11]. Through the kneading process, inside dough, complex modifications of substances take place, the most important being the coloidal and phisio chemical processes [8]. The quality of bread depends on the way the kneading process is made (type of kneader, angular speed of the kneading arm, kneading time and the percentage of added water) [3,4]. The way the dough is mixed has a major impact on the rheological properties due to the time- and strain-dependent nature of dough. An intensive type of kneading for a long period of time leads to the destruction of protein structure and formation of a secondary one, weaker. A dough is well kneaded when it present itself as a tight, homogeneous mass, dry at the surface, elastic and gets off easily from the kneading arm and vat's walls. The farinograph and mixograph are two common devices for assessing flour properties during mixing in lab scale. Both mixers provide empirical measurements related to the torque and work input required to produce optimally mixed dough, despite dissimilar geometries and mixing actions.

For achieving the proper dough development, two basic requirements must be satisfied. The imparted mixing energy or work input must be higher than the critical limit of energy needed for gluten formation, and the mixing intensity must be above the critical level for the dough development [7]. These requirements vary with the flour properties and the type of mixer used [12,13].

Taking all this into consideration, every lot and type of flour must be adapted to the specific technology of every factory. In most breadmaking factories, the optimal kneading is based on worker's experience and less on scientific data, fact which determines great inconsistencies in the process. Recently, a number of analytical methods have been investigated to monitor dough development based on physical or chemical description of dough properties. The most popular in-line process measurements, based on changes in dough physical properties, are that of mixing torque or power consumption of the mixer.

A clear image over the kneading process is of great importance because it can offer indicators for optimal dough development (gas retention, elasticity, behaviour in dividing and modeling process), which will decide the quality of the end product, [1,2,7], and the decisions based on experience or intuition can be limited with the help of an integrated measuring and control system, for dough consistency and forming.

The purpose of this paper is to study the impact the type of kneader has over the rheological proprieties of the obtained dough, using the same flour, type 650 from 7 Spice, in similar conditions of temperature, added water, time of kneading.

MATERIALS AND METHODS

The experimental determinations for flour quality evaluation were done using a Brabender farinograph, version E (figure 1a), with a 300g flour capacity. Tests were also made using three different types of kneaders, at which was connected a data aquisition and measuring device for consumed current at the engine of the kneader, called " Loggit" (figure 1b).

Fig. 1 a: Brabender farinograph; b: Portable device for measuring the consumed current at the kneading arm

During kneading, the consumed energy increases or decreases, based on the opposing force of dough at the kneading arm, respectively the moment (Nm) registered at the kneading arm(s).

In order to filter the obtained data, functions like max, min, average, count and others in the Excel program were used. At first, the mixer was left working without load (out-current), in order to establish the energy losses of the kneader, which were decreased from the final calculation of the torque (Nm) consumed by the spiral blade, in relation with the opposing force of the dough.

Considering the general relation for calculating the necessary driving power on the working arm, it can be written:

$$P = M\frac{\pi n}{30}\ [\text{kW}] \qquad (1),$$

where: M is the resisting torque at the kneading arm, maximum, respectively medium and P is the corresponding power.

For finding the power consumed by the mixer's engine, the following relation was used:

$$P = \sqrt{3}UIcos\phi\ [\text{kW}] \qquad (2),$$

where: U is tension of the current, I is the intensity of the current and which is the value measured by the clamp and is the power factor.

In order to establish the consumed power by the kneading process, without the energy losses, the next relation was used:

$$P_f = P - P_g\ [\text{kW}] \qquad (3),$$

where: P_f is the consumed power only for the kneading process, P is the total power consumed by the mixer's engine and P_g is the consumed power of the engine, on out-current.

Knowing the consumed power for the kneading process and the angular speed described by the kneading arm, it is possible to calculate the medium torque, as it follows:

$$M_m = \frac{P}{\omega}\ [\text{N.m}] \qquad (4),$$

where: Mm is the opposing medium torque at the kneading arm, P_m is the power consumed by the engine only for the kneading process and ω is the angular speed of the arm when kneading [11].

If, during kneading,the torque at a kneading shaft is measured, it is obtained a curve M=f(t), which is presented as the one in figure 2.

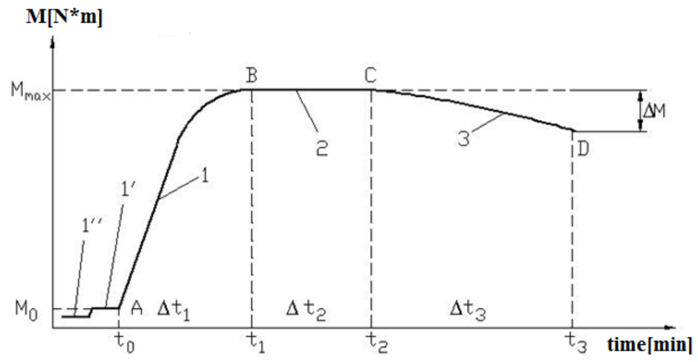

Fig. 2 Moment variation at the kneading arm [11]

In this figure, the portion for 1" represents the registered values for working without load and 1` is the moment after introducing the flour in the vat.

AB – hydration of flour;

BC – maximum torque and stability;

CD – softening phase when prolonged the kneading;

- Δt1 – time for dough forming
- Δt2 – stability time;
- Δt3 – softening period [11].

For the experiments, it was used a single lot of flour, 650 type, with the phisico - chemical characteristics shown in table 1.

Table 1 Physio –chemical characteristics of 650 type flour used in the experiments

Flour type	Moisture content, [%]	Wet gluten, [%]	Ash, [%] d.s.	Gluten deformation [mm]	Acidity, [degrees]	Falling number, [sec]	Gluten index
FA – 650	13,8	28.4	0.65	3,5	2	323	92

The pharinogram (figure 3) gives indications for the percentage of water absorption, dough developing time, stability period and the degree of softening. The result for the used flour are shown in table 2. For the analisys of a pharinogram, it is taken into consideration the curve described by the medium values between maximum and minimum, registered as opposing force at the kneading arm.

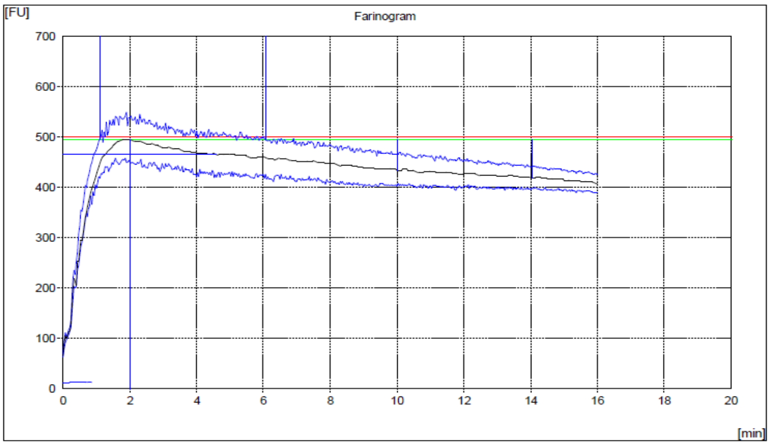

Fig. 3 Farinogram obtained for the flour used in the experiments

Table 2 Result obtained after farinogram analysis

Flour type	Water absorption, [%]	Development time, [min]	Stability [min]	Degree of softening [FU]
FA – 650	58.5	2	5	61

Doughs were kneaded using the following types of kneaders: Diosna Spv 240 A, with spiral blade and mobile vat (figure 4b), planetary kneader Polin MR – with two vertical arms (figure 4a), horizontal kneader HD 2600 with horizontal spiral arm (figure 4c,d). Technical characteristics of these kneaders can be seen in table 3. For the tests, it was used the maximum capacity recommended by the producer : 240 kg of dough for diosna SPV 240 A, 160 kg of dough for HD 2600 and 70 kg of dough for Polin. The quantity of added water in the three experiments was of 58.5 % calculated for the amount of flour used.

Table 3 Technical characteristics for the three kneaders

Technical data	Polin - MR 140	Diosna SPV 240	Mixer HD 2600
Capacity (kg of dough/hour)	700	2400	2600
Dough quantity per batch (kg)	70	240	160
Number of batches /hour	10	10	16,25
Installed power (kW)	7,5	18,5	55
Total installed power (kW)	7,5	18,5	55
Current (V)	380	380	380
Frequency (Hz)	50	50	50
Kneader weight (kg)	1300	1800	1800

The Polin kneader is equipped with a frequency variator, which allowed us to do three kneadings with the same equipment, but at different speeds of the kneading arms. The same flour was used, with the same quantity of 58.5 % of added water, calculated for 70 kg of dough.

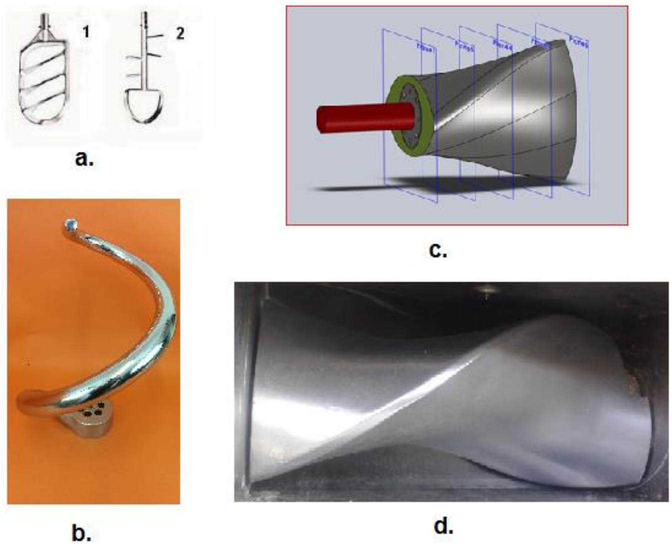

Fig. 4 The kneading arms used for the tests: a. Polin, b. Diosna, c,d. HD 2600

RESULTS AND DISCUSSIONS

The tests were made with the three types of kneaders, keeping identical parameters: the same lot of flour 650 type was used for all the tests, the same time of kneading and temepartures for environment, flour and water; the amount of added water was 58.5 % for all kneading sessions, and the vats were loaded at maximum capacity recomended by the producer.

For the second part of the paper, the results obtained during kneading, can be observed in the resulting diagrams (figures 5,6,7,8).

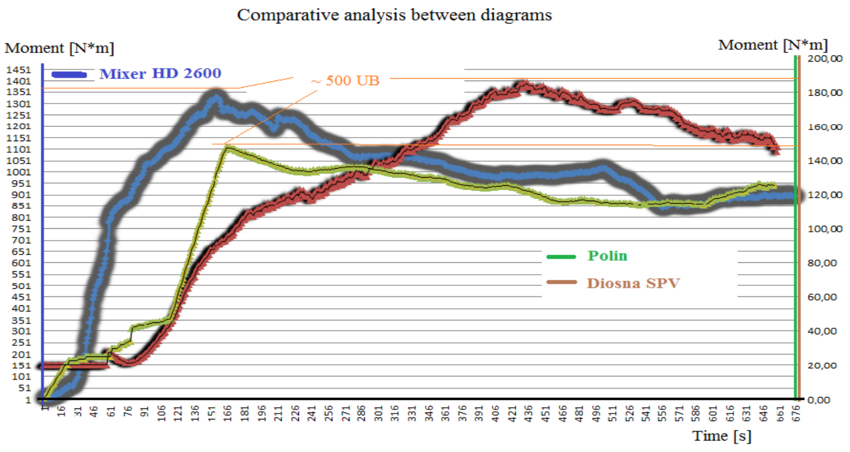

Fig. 5 Comparative analysis between kneading diagrams

In figure 5, can be observed the differences in shape of the kneading curves, which show the different tendency of dough development by modifying the time necessary to form the gluten structure, which changes the entire rheological characteristics of dough with later influences over the technological process.

The rapid forming of a gluten structure attracts with itself the acceleration of softening processes and a reducing in stability time. This phenomenon is also available in the case of slow forming of gluten structure (slow speed kneading, for a long period of time), and the results are much more relevant in the case of flours of weak to medium quality.

It can be observed that the first kneader which reaches a maximum moment is HD kneader; it introduces an energy of 15 w*h/ kg, followed by Polin kneader with 5.6 w*h/kg and the last one is Diosna kneader, with 4.8 w*h/kg.

Once with the growing energy transfered to the dough, the time of kneading decreases, because the dough reaches a critical level of deformation in a smaller time unit. With this analisys, it can be observed that none of the kneading curves describes a comparative model with the one obtained by Brabender.

Based on this kneading diagrams, it can be established: the hydration period of the ingredients, the formin of dough, the stability time and the softening degree.

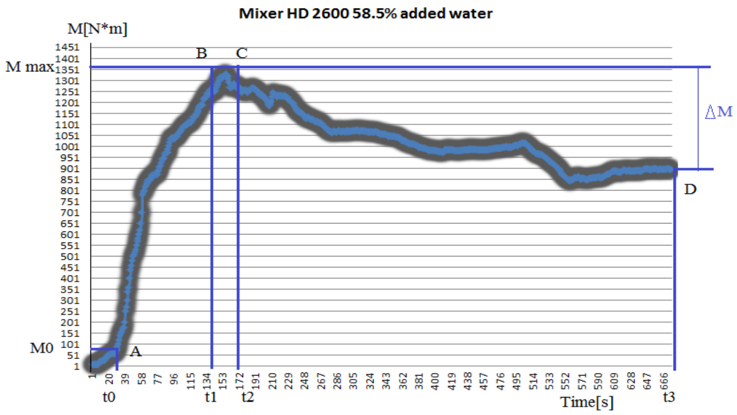

Fig. 6 Kneading diagram for HD 2600

Dough kneaded with HD 2600 kneader has a little formation time because the amount of energy which is transferred to the dough when it enters in contact with the surface of the kneading arm and the vat is great, in a very short period of time. This type of kneading responds very well for strong flour, which requires reduction systems (to supplement the need for softening). For the type of flour used, the optimal kneading time is 180 seconds, because after this point, doughs stability ends and the degree of softening starts to rise gradually.

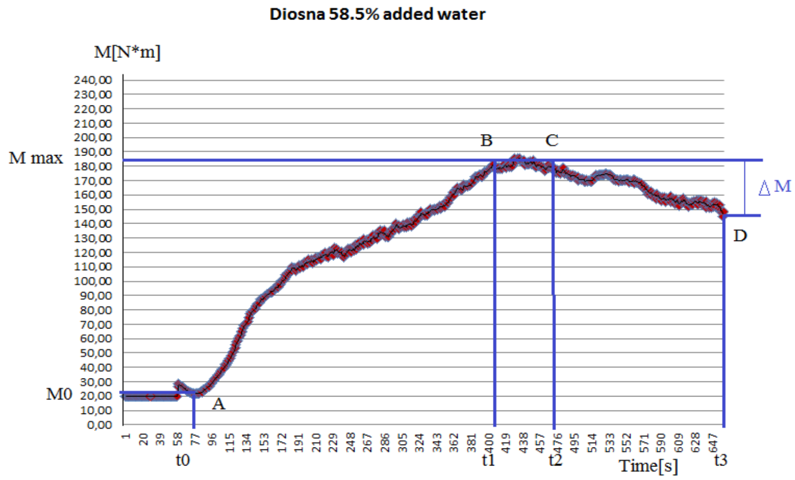

Fig. 7 Kneading diagram for Diosna SPV 240A

Diosna kneader has an optimal kneading time of 8 to 12 minutes and the time for optimal dough development is three times bigger than for HD 2600 kneader. It can be observed that the stability time is also greater; this fact is directly dependent on the formation of gluten structure, during kneading period. Also, the softening process for this dough is slower, because the softening degree reaches 22% versus 33% for the kneading process with HD2600 kneader and 26% for the kneading process using Polin, as it is shown in table 4.

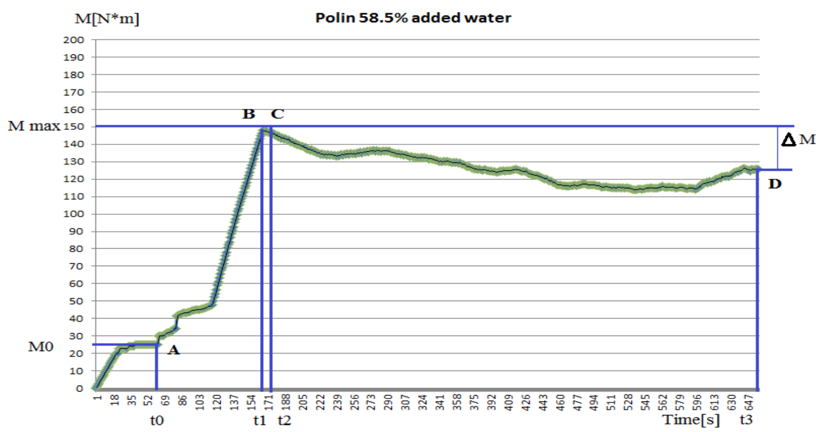

Fig. 8 Kneading diagram for Polin

Dough kneaded with Polin has a quick formation, followed by a little stability period and registers 26% degree of softening until the ending of kneading process.

In table 4 below, can be identified the values obtained for the periods described in the kneading diagrams (AB – flour hydration, BC –maximum moment and stability period, CD – dough softening).

Table 4 Values obtained for the three tests, after the analysis of kneading diagrams

Kneader type	AB [N.m]	BC [N.m]	CD [N.m]	Δt1 [s]	Δt2 [s]	Δt3 [s]
Diosna SPV	150	185	40	30	70	170
Mixer HD 2600	1260	1360	450	110	35	495
Polin	125	150	40	110	18	470

The third part of the paper presents the differences registered in the performed tests on Polin kneader, at different speed of the kneading arms (figure 9), after the values for the energy losses when working without load were decreased. For this experiment, the vat was loaded at full capacity indicated by the manufacturer (70kg of dough) and every batch was made in similar conditions. All three tests were made with the same recipe: 58.5% water, 2% salt and 3% yeast. For 4.1 W*h/kg, the kneader was set at 100RPM, for 5.6 W*h/kg, it was set at 150 RPM and for 7.2 W*h/kg, the speed was 200 RPM.

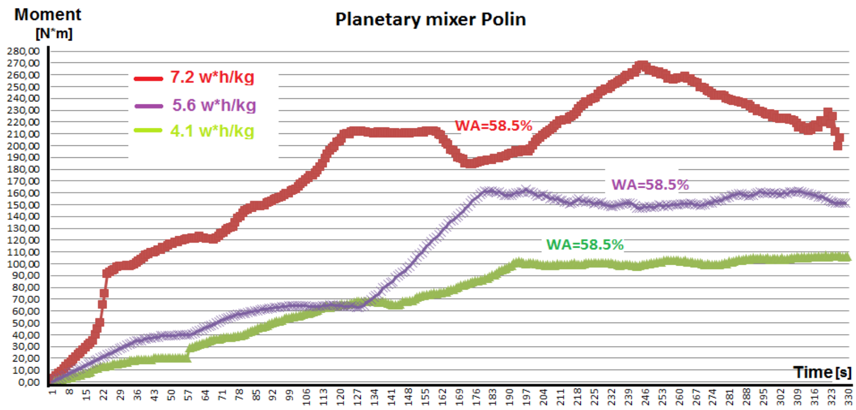

Fig. 9 Kneading diagrams obtained with Polin, at different set speeds

It is possible to observe the different development of each dough, strictly influenced by the quantity of energy transferred into dough in the same time unit, with the same recipe and working conditions. The necessary time for dough development and time stability are directly reported to the amount of energy introduced.

From the results obtained, it is possible to conclude that the best dough development was the one which received 5.6 W*h/kg, because for this value, the maximum consistency has a good level, the stability time is greater than the other two. So, it can be said that once with a higher level of energy introduced into dough, it grows the stability time and after reaching a critical level of energy, the stability reduces gradually.

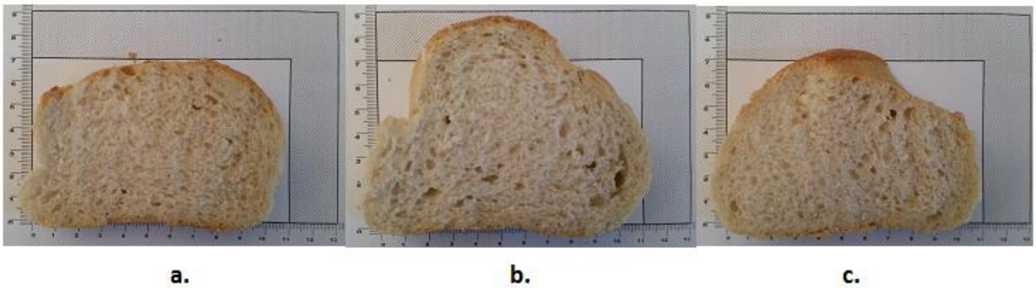

Fig.10 Final product obtained with: a. 4.1 W*h/kg; b.5.6 W*h/kg; c. 7.2 W*h/kg

In figure 10 can be seen the effect of dough stability and gluten structure development over gas retention and extensibility of gluten structure; these effects lead to products with higher volume.

The energy introduced in the kneading process is a good indicator for optimal dough development. The amount of added water can be correlated with the quantity of introduced energy into dough in time unit, if it is known the optimal dough consistency. Knowing that water acts as a reducing agent also, by controlling the energy and the resistant moment at the kneading arm, it is possible to establish the quantity of added water, necessary for every flour and technological process.

In bread making industry, reducing agents like L-cysteine are used to soften the flour, which require extra costs. They can be eliminated through a good control of the quantity of added water and by introducing the optimal amount of energy in time unit, depending on the rheological proprieties of the used flour.

CONCLUSIONS

The results obtained in this paper showed the differences between kneading diagrams from three different type of kneader. For all the experiments, was used the same type of flour (650) from the same lot, with the same quantity of added water to each batch of dough.

The rheology of dough was influenced b the speed with which the energy was transferred to the dough, which influenced directly the final product (structure, color, crumb, etc.).

The mechanical development obtained during intensive kneading brings a beneficial oxidizing effect, which improves the rheological effects of dough and crumb color.

In order to raise the accuracy in adapting the flours to industrial bread making processes, at each industrial kneader, can be set a device which can monitor and display in real time dough consistency and the level of introduced energy into each batch.

For a beneficial and optimal mechanical development, it is necessary to analyze every type of kneader and the characteristics of the flour used in each process and establish an optimal working regime adapted for each desired final product and the entire industrial process.

It is possible to conclude that up to a certain value for the energy introduced into the dough, thanks to a pronounced globular opening of the proteins, these hydrate better, which allows for a higher level of consistency, if the mechanical development is controlled.

The kneading diagram can develop very differently, even using similar conditions (same flour, temperatures, added water), if the value for energy introduced is changed.

This data will be further used to develop a device which will optimize the kneading process by automatically correlation between the flour characteristics and the requirements of the industrial process.

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