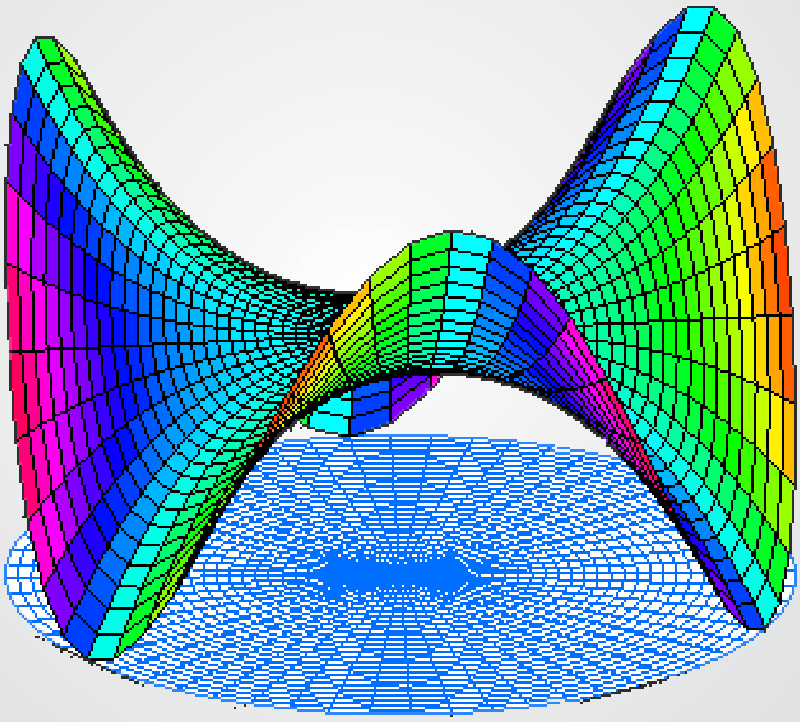
Journal of
# Food and Packaging
Science, Technique and Technologies



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ISSN 1314-7773

ISSN 1314-7773

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# Journal of
# **FOOD** and **PACKAGING**
# Science, Technique and Technologies

Year V, №9, 2016

*National Academy of Packaging - Bulgaria*

CONTENTS

# DETERMINATION OF THE MAIN STAGES OF MIXING WHEAT SOURDOUGH RELATIVE METHOD

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**Abstract.** *The optimum duration of the cooking liquid wheat sourdough for the proposed design of the mixer was determined by fixing the beginning of time, during which the amount of torque on the outside of the mixing bowl was at the same level for a certain period of time. Slots began to form structures have been identified in the system of the flour / water, the time to reach the maximum resistance of the system, and the start time balancing system as an indirect factor in product availability.*

**Keywords:** sourdough, mixing time, structure, torque, 3D printing

## I. Introduction

In academic publishing, usually considered those properties of disperse systems, in which the process of forming the structure is substantially complete, i.e. for further studying is taken that product sample, which already prepared in some way. Therefore, the kinetic regularities of the mutual distribution of liquid and solid phases, which is the initial stage of formation of disperse systems (mixing step), remain outside the field of view of researchers. Meanwhile, it is obvious, that this stage is important in the formation of dispersed systems. It is in the early steps of structure formation, from the moment of contact of particulate phase with each other and with the liquid medium, where a base for the future two-phase structure in a highly dispersed system is building. The most important characteristic of such systems – the homogeneity of their structure – is achieved by a result of equiprobable distribution of solid and liquid phases [1].

The sourdough is prepared by mixing flour and water and with adding substances which stimulating fermentation [2]. When mixing wheat flour with water, there can be obtained several kinds of output material depending on the amount of water, which is added – a large water amount gives liquid suspension. In the sourdough, water can be ‘bound’ and ‘free’. Bound water is part of the hydration shell, has limited mobility and gives increased resistance to the sourdough, compared to water.

The main flour components include natural macromolecular compounds – proteins and polysaccharides (starch). Starch, proteins, which is responsible for the formation of the product. Starch granules plays a key role during the baking stage, but at the phase of mixing their part is minor [3]. Obviously, the starch granules cause strong nonlinear behavior of the rheological characteristics of flour slurries.

A process of formation sourdough from a flour is taking place by swelling and increasing the weight and volume of the macromolecular compounds because of absorption of low-molecular water. For the starch, degree of swelling is around a few percent; for a protein, it can reach 200 %.

As a result of proteins limited swelling, the sourdough gains viscous consistency. When a part of the proteins goes to dissolved state, the properties of sourdough decreasing: it becomes liquid and tacky. In this case, swelling can be unlimited.

Flour particle size largely determines main properties of the sourdough. A human eye can observe particles of wheat flour; their size range vary from 1 to 100 microns [3]. This particular type of flour belongs at the same time to the medium and coarse disperse system. Such specific dimensions gives the sourdough qualities, which primarily connected with a size of an interface between the particles and the water, thus its specific surface area will be about 500 $m^2$/kg.

A desire to reduce the interfacial area is expressed by spontaneous enlargement of flour particles. Also, sticking of particles leads to the formation of aggregates. As smaller particles are, as higher their intension to enlargement. Therefore, formation of aggregates and even lumps consisting of a plurality of particles (this process is called coagulation) is natural for the flour.

A fragmentation, harsh increase of the interface area in combination with a large excess of the surface energy leads to the fact that the system is non-equilibrium and tends to move in a more stable equilibrium state.

In a late 20s of the last century, *Deryagin B.V.* formulated the concept of a three-dimensional approach to the properties of liquid interfacial layers, including those between the particles of the dispersed phase. Not only the linear dimensions, length and width of these layers, but mainly their structure depending on the thickness (third dimension) has a decisive effect on the properties of systems with liquid dispersion medium [3].

Thereby, the interfacial layers turned into a means of predetermining the properties of dispersed systems. Among these properties are the contact interaction and structure formation.

Contact interaction reflect the result of touches between solids – the dispersed phase particles with each other (autohesion) – when there is no movement of the body. In dynamic conditions, contact interactions forms the strength of the structured bodies.

Also, it is hard to measure properties of such system, because they are constantly changing due to physical and chemical factors (evolution of components interaction water / flour system, enzymes reactions, stress relaxation) arising in a process of mixing.

## II. Materials and methods

A material for the research was the liquid wheat sourdough with moisture level is 65 %. Sourdough was made from wheat flour: flour's moisture was 13,9±0,2 %, without the addition any extra components. Sourdough temperature kept at level 28 ± 1 °C. Prepared sourdough had a volume of 0.006 $m^3$, while the density of sourdough $\rho$ = 1066 $kg/m^3$.

Determination of the torque values on the exterior of the cup was performed using the experimental setup (Fig. 1) with a cylindrical cup internal diameter of which D = 260 mm, an induction coupling for adjusting the operating speed and the drive unit, consisting of an induction motor power of 0,6 kW, and V-belt transmission.

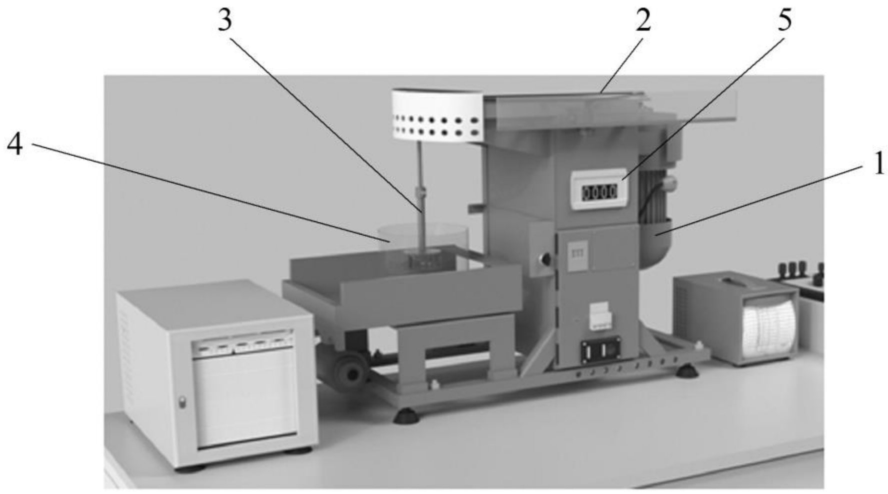


**Figure 1.** *Experimental mechanism:*
*1 - electric motor, 2 - V-belt drive, 3 - a shaft with a movable operating element,*
*4 - transparent cylindrical cup, 5 - electronic tachometer*

A complex geometry installation setup form of movable operating elements was implemented with the help of 3D printing technologies, namely by additive parts manufacturing from PLA or ABS plastic. This technology allows to develop a prototype according to three-dimensional drawings (Fig. 2) using an appropriate automated software; to generate various internal structures (inside of the 3D-model); to set up and change the mass-inertial characteristics of the working body – to make it fully a flexible, elastic, and so on.

Movable operating element dimensions (outside diameter) depends on the internal bowl diameter D and, accordingly to previous data, equals 1/2 bowl's part. In other terms, it was 130 mm, and its weight was equal to 283 grams. Printed on a 3D printer element is shown on Fig. 3.

The device with that specific movable operating element had been patented on utility models [5].

The purpose of our research was to determine the availability of liquid wheat sourdough. That has been implemented by the method of fixing the torque on the cup (secondary torque), in which sourdough was prepared. Such a method in the academic publishing called a mechanical and apparatus for measuring it – a dynamometer.

The cup was placed on a rotating plate and the time of quantity counterweight during operation of the mixer was measured. That period was taken as an equivalent of torque on its shaft.

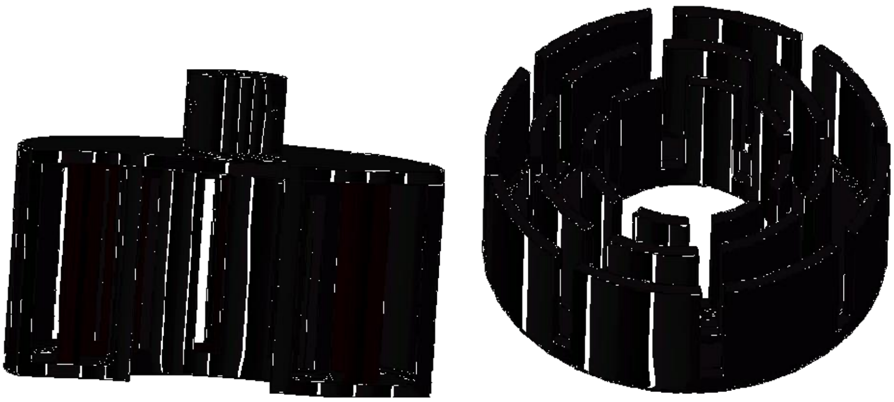

**Figure 2.** *3D model of the movable operating element of the mixer in cutaway*

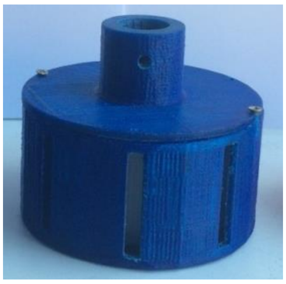

**Figure 3.** *Photo of movable operating element printed on a 3D printer*

In our experiment, stirrer with movable operating element, whose size equal 1/2D of bowl's size, was rotated at 500 rev/min, while water at 30 °C and the volume of 0,0036 $m^3$ was poured in the cup. At some point of time, we added (with a constant speed) the 2400 grams of flour in a bowl with water and rotating the movable operating element. The time interval between portions of flour was added is $t \approx 24$ seconds, i.e. flour adding rate was 100 g/sec.

A resistance, which a test sample is showing in process of mixing is proportional to its viscosity and can be simply measured by an electronic balance in a form of force arising at the outer radius of the mixer bowl. Therefore, at the same time value of force $F$ was fixed in grams by an electronic balance.

With a relative to the axis of the machine a fluid rotational motion is working equilibrium of moments condition, which is expressed in the form of torque equality, applied to the liquid while stirrer blades are moving, and the moment of resistance at the walls and bottom of the apparatus. Starting from this condition, thus, measurement of the secondary torque on the machine's circumference bowl with a mixer is not too difficult. Measured at the shoulder certain amount of force, which does not allow rotation of the bowl, multiplied by the radius of the cup itself by the formula:

$$T = F \times r, \quad (1)$$

$T$ – torque, N×m, $F$ - the force on the radius $r$ from the rotation axis, N, $r$ - the radius of the bowl ($r$ = 0,13), m.

That point in time was measured for 400 seconds. On "rheogram" you can see torque vs time graph.

## III. Results and discussion

Wheat sourdough for bakery products is a complex mix of interacting components. Despite the fact that this system, actually, is an aqueous, it contains several dispersed phases – air and starch crystals. If kneaded sourdough has a weak structure, these phases separated easily. In this case, a dense rubber-like layer of destroyed starch are forming in the bottom of a product, meanwhile upper part of product becomes porous due assembled air bubbles. A well-chosen mixing mode can stop the phase separation, but cannot be a guarantee of high quality baked products [6].

The first step of preparation of the liquid sourdough is blending components: soluble components of flour and other ingredients are dissolving, and the insoluble components becomes hydrated. Other important consequence of mixing process is air saturation of the sourdough. Once sourdough is prepared, there is no way new air bubbles can exist inside of sourdough, while already existing air bubbles can disappear in way of rising to the surface or merging with one another.

Wheat flour contains several unique proteins, gliadins and glutenins, which are not present in other cereals. Hydration of these particular proteins gives a gluten. The gluten structure formation follows a physicochemical processes which occurring at the molecular level.

Thus, the data of force *F* received in the experiment recalculated in Newton and by the formula (1) found torque value. The results shown in Table 1 and a rheogram built in Fig. 4.

**Table 1.** *Torque variation on the bowl of the mixer*

| Time *t*, sec | The force *F* to the outer radius of the bowl | | Torque *T*, N×m |
|---|---|---|---|
| | gram | newton | |
| 1 | 2 | 3 | 4 |
| 11,9 | 15 | 0,147 | 0,019 |
| 13,77 | 20 | 0,196 | 0,025 |
| 14,21 | 25 | 0,245 | 0,032 |
| 14,41 | 30 | 0,294 | 0,038 |
| 14,71 | 35 | 0,343 | 0,045 |
| 14,8 | 40 | 0,392 | 0,051 |
| 15 | 45 | 0,441 | 0,057 |
| 15,17 | 55 | 0,539 | 0,07 |
| 15,21 | 65 | 0,637 | 0,083 |
| 15,3 | 80 | 0,784 | 0,102 |
| 15,5 | 85 | 0,833 | 0,108 |
| 15,7 | 95 | 0,932 | 0,121 |
| 15,9 | 105 | 1,029 | 0,134 |
| 16,1 | 120 | 1,177 | 0,153 |
| 16,2 | 130 | 1,275 | 0,166 |
| 16,27 | 135 | 1,324 | 0,172 |
| 16,3 | 145 | 1,422 | 0,185 |
| 16,94 | 150 | 1,471 | 0,191 |
| 17,23 | 155 | 1,52 | 0,198 |
| 17,41 | 160 | 1,569 | 0,204 |
| 17,59 | 165 | 1,618 | 0,21 |
| 17,8 | 170 | 1,667 | 0,217 |
| 17,91 | 180 | 1,765 | 0,229 |
| 18,21 | 190 | 1,863 | 0,242 |
| 18,41 | 205 | 2,01 | 0,261 |
| 18,7 | 210 | 2,059 | 0,268 |
| 19 | 220 | 2,157 | 0,28 |
| 19,1 | 225 | 2,206 | 0,287 |
| 19,2 | 230 | 2,255 | 0,293 |
| 19,42 | 240 | 2,354 | 0,306 |
| 19,62 | 270 | 2,648 | 0,344 |
| 19,7 | 280 | 2,746 | 0,357 |
| 19,9 | 295 | 2,893 | 0,376 |
| 20,02 | 305 | 2,991 | 0,389 |
| 20,22 | 325 | 3,187 | 0,414 |
| 20,4 | 330 | 3,236 | 0,421 |
| 21,72 | 350 | 3,432 | 0,446 |
| 21,82 | 365 | 3,579 | 0,465 |
| 21,9 | 385 | 3,776 | 0,491 |
| 22,22 | 380 | 3,727 | 0,484 |
| 22,61 | 375 | 3,678 | 0,478 |
| 23,2 | 380 | 3,727 | 0,484 |
| 23,81 | 375 | 3,678 | 0,478 |
| 24,5 | 385 | 3,776 | 0,491 |
| 24,77 | 395 | 3,874 | 0,503 |
| 24,87 | 400 | 3,923 | 0,51 |
| 25,51 | 395 | 3,874 | 0,503 |
| 25,9 | 390 | 3,825 | 0,497 |
| 26,4 | 385 | 3,776 | 0,491 |
| 26,6 | 380 | 3,727 | 0,484 |
| 26,8 | 375 | 3,678 | 0,478 |
| 27,24 | 370 | 3,628 | 0,472 |
| 27,65 | 365 | 3,579 | 0,465 |
| 28,5 | 360 | 3,53052 | 0,459 |
| 29,93 | 355 | 3,481 | 0,452 |
| 30,53 | 350 | 3,432 | 0,446 |
| 31,2 | 345 | 3,383 | 0,44 |
| 32,31 | 340 | 3,334 | 0,433 |
| 33,4 | 335 | 3,285 | 0,427 |
| 34,2 | 330 | 3,236 | 0,421 |
| 36,7 | 325 | 3,187 | 0,414 |
| 37,67 | 320 | 3,138 | 0,408 |
| 38,17 | 325 | 3,187 | 0,414 |
| 38,88 | 320 | 3,138 | 0,408 |
| 40,4 | 315 | 3,089 | 0,401 |
| 42,59 | 310 | 3,04 | 0,395 |
| 43,14 | 305 | 2,991 | 0,389 |
| 44,65 | 300 | 2,942 | 0,382 |
| 45,2 | 295 | 2,893 | 0,376 |
| 47,55 | 290 | 2,844 | 0,37 |
| 48,64 | 285 | 2,795 | 0,363 |
| 49,18 | 280 | 2,746 | 0,357 |
| 49,99 | 275 | 2,697 | 0,351 |
| 50,67 | 265 | 2,599 | 0,338 |
| 52,6 | 260 | 2,55 | 0,331 |
| 53,53 | 265 | 2,599 | 0,338 |
| 55,19 | 260 | 2,55 | 0,331 |
| 56,7 | 255 | 2,5 | 0,325 |
| 59,4 | 250 | 2,452 | 0,319 |
| 63,9 | 255 | 2,5 | 0,325 |
| 64,8 | 250 | 2,452 | 0,319 |
| 78,3 | 240 | 2,354 | 0,306 |

| | | | |
|---|---|---|---|
| 79,12 | 235 | 2,305 | 0,299 |
| 82,67 | 230 | 2,256 | 0,293 |
| 93,52 | 225 | 2,206 | 0,287 |
| 110,32 | 220 | 2,157 | 0,28 |
| 130,52 | 220 | 2,157 | 0,28 |
| 132,82 | 215 | 2,108 | 0,274 |
| 209,92 | 215 | 2,108 | 0,274 |
| 238,02 | 210 | 2,059 | 0,268 |
| 239,72 | 205 | 2,01 | 0,261 |
| 265,12 | 200 | 1,961 | 0,255 |
| 368,72 | 195 | 1,912 | 0,249 |
| 391,82 | 190 | 1,863 | 0,242 |

According to received data, by 11,9 seconds after the beginning of adding 1190 gr of flour to the bowl, torque starts to provide resistance to the rotating movable operating element due to beginning of a structure formation in the flour/water system. Then increasing in a high speed, changing by 0,01 N×m for each 0,1 second. At $t$ = 24,22 sec flour is fully added in a bowl of water, that point is marked by a dotted vertical line in Fig. 4. Torque max value 0.51 N×m is reached at $t$ = 24,87 seconds.

Further observation indicates that once reached its maximum, torque starts to decrease (Fig. 5). However, that action last longer, then process of growth in the initial period. Torque value reduced by 0,005 N×m each 1 second, which is about 20 times slower than the speed in the first stage.

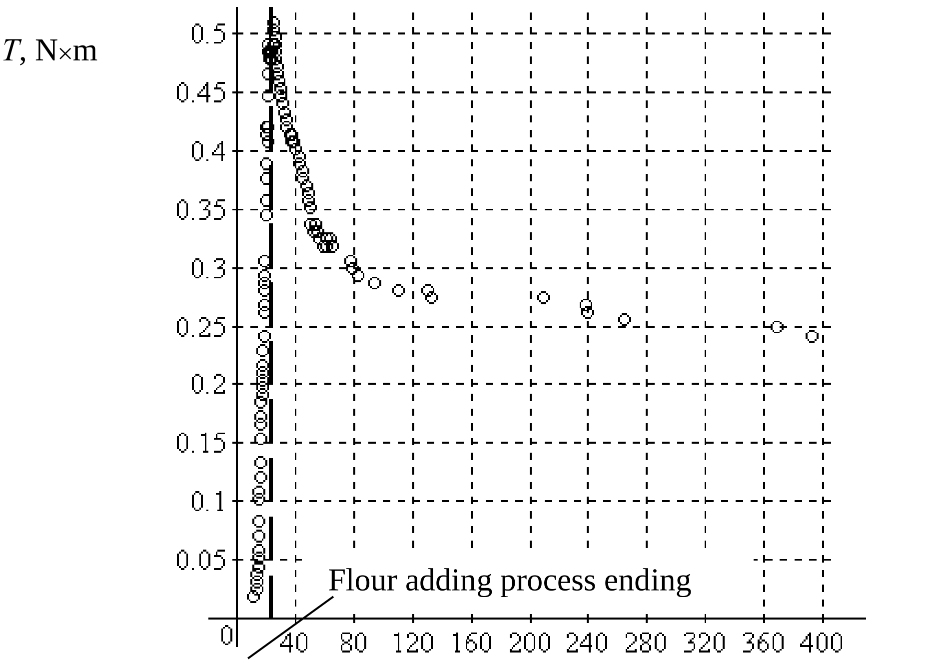


**Figure 4.** *Torque on the circumference of the bowl shaft v*

At time of ~80 seconds, torque intervals changes increased to 10 seconds, which may indicate, that the system in a process of balancing and the product ready. The final moment of system balance reaches around ~133 seconds while torque value decreases to 0,274 N×m, showing 54% of its maximum value.

Subsequently, the curve does not change significantly due to process of the sourdough over mixing, which increases the energy expenses.

Rheogram data with further calculating gives ability to determine the quantity of flour need to increase torque value up to 70 % of the maximum. According to that, it be 1970 grams or 82 % of a total weight of the flour. This is the amount of flour is considered the typical, which determines a component absorptive capacity. Saying on baking terminology - water absorption ability of flour, knowledge of what needed to understand and represent the further behavior of sourdough during processing.

## IV. Conclusion

Torque curve position of in Fig. 5 can be explained by fact that the flour and water at the initial stage start to quickly agglomerate and form lumps, which result in structure's viscosity and, respectively, the torque increases sharply. That happens cause of increasing in numbers of contacts between the flour particles in the bowl volume.

At the beginning of the mixing process, there is a large amount of free water. Flour particles are independent from each other, noticing a predisposition to the mix. Then flour comes hydrated and amount of free water reduced in way, that the adhesion of the system is increases. Gradually, gluten macromolecular network develops.

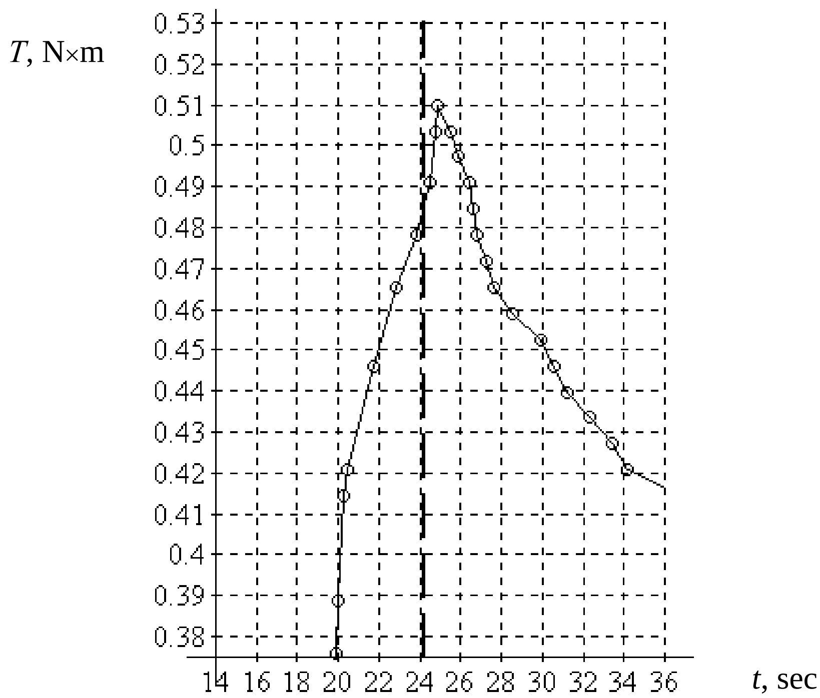


**Figure 5.** *Area of peak torque values on the mixer shaft*

In the next stage, after reaching the maximum torque value, under external mechanical action the solid spatial structural grid breaks, accompanied by the loss of the fixed positions of particles in the system volume. It leads to a loss of kinetic stability, especially if the particles or aggregates of particles have relatively big sizes.

At the final stage due to mechanical impacts sourdough acquires that dynamic state in which all reversible contact between the particles of flour are destroyed and greatest flow ability at the lowest level of viscosity (lowest viscosity level at destroyed structures)is realized.

Thus, the relative rheometry can give important information about the material ability to the processing, which absolute rheometry cannot. However, absolute and relative rheometry are complement one another. Due to inherent benefits and limitations to each of these methods, their combined use will lead to greater understanding of the material behavior at the required processing step, than the use of them individually.

Thus, a control of change the amount of torque on the driving mixing elements, during mixing process of wheat sourdough, allows you to create a conceptual view of a heterophase structure which product obtained and set the required amount of water and blending mode for prescription ingredients.

## Acknowledgments

Administration of National University of Food Technologies in particular Dr Eng. Assoc. Prof. I. Litovchenko is gratefully acknowledged for scientific supporting.

## References

[1] Uriev N.B., Potanin A.A. The fluidity of powders and suspensions. – M.: Himiya, 1992, 256 p.

[2] JongenT.R.G., Bruschke, M.V., Dekker, J.G., 2003. Analysis of dough kneaders using numerical flow simulations. Cereal Chemistry 80, pp. 383-389.

[3] Letang C., Piau M., Verdier C., 1999. Characterization of wheat flour-water doughs. *Journal of Food Engineering* 41, pp. 121-132

[4] Zimon A.D. Entertaining colloid chemistry. 4 edition. – M.: Agar, 2002, 168 p.

[5] Device for mixing liquid semi finished products: pat. 103656 Ukraine IPC A21C 1/02 / Y.Y. Dolomakin, I.M. Litovchenko. – u2015 06039, appl. 18.06.15, publ. 25.12.2015, Official bulletin. № 24 – 4 p.

[6] Delcour J.A., Hoseney R.C., 2010. Principles of cereal science and technology. Amer. Assn of Cereal Chemists, 3 edition, 280 p.