Determination of Mathematical Relation for Necessary Mass of Dough for Obtaining Bread with Defined Mass

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*M. Bocevska**, *T. Dimeski, and I. Aldabas*

Faculty of Technology and Metallurgy, University "St. Kiril and Metodij" ,
Rudger Boskovic 16, P.O.B. 580, 1000 Skopje, Macedonia
E-mail: mirjana@ereb1.mf.ukim.edu.mk

The bread was prepared from various types of flour: T-400, T-500, T-850 and T-1000 and manually divided into pieces of dough with exact mass of 650, 700, 750, 800, 900 and 1000 g. An increase of loss of mass with an increase of mass of dough, independently of the used type of flour was confirmed. However, the loss of mass decreased among the pieces of dough with the same mass, with an increase of type of flour. A strong linear correlation (R^2 = 0.99) was confirmed between mass of dough and mass of bread after 3 hours of storage. Quantitative connection of mass of bread and necessary mass of dough was established as the equation of the first order, m_{Dough} = 45.654 + 1.0624 $m_{\text{CBread (3 hours storage)}}$. Its validity was tested and confirmed by following the data for mass of dough and bread of 600 g obtained of flour type T- 500 in industrial process.

Key words: *Mass of dough, mass of bread, mathematical relation*

Introduction

The bread has a primary role in nutrition of the people from this region. However, changes in lifestyle urbanization and industrialization have also brought about changes in the food supply. Thus in the last thirty years a significant intake of pastries and bakery products caused decrease in bread consumption. It imposed correction of the loaf mass. Namely its mass from 1000 g in the early the seventies was decreased to 800 g in the eighties and 600 g in the nineties. Today the mass of common loaf is only 550 g. Nevertheless, as many years ago, when bread is bought the consumers ask for one loaf, two, or more, never minding that this loaf is almost the half in the mass in comparison with previous one. The most important is the fact that it satisfies the demands of the consumers. Today they can choose from a rich assortment of (dietary, high-quality nutritious or specifically fortified) types of bread. However, the bread of flour T-500 is still the most commonly used. Its quality is improved by using different kinds of additives. It is especially evident in its porosity and volume. The satisfactory volume in many occasions could mask the mass of the loaf. The long term control of the bread from the market have shown a great variation of its mass. The mass of bread has varied up to ±15 % in compare with declared. It means this variations are three times higher than 5 % which are prescribed by the regulations.[1] In depends of situations. It is unfavorable for consumers or manufacturers.

The first demand for obtaining bread with defined mass is dividing the dough to pieces with necessary mass. It is well known relation[2]

$$m_D = \frac{m_{CB}10\ 000}{(100 \quad w_B)(100 \quad w_C)} \tag{1}$$

where: m_D- is mass of dough , m_{CB}-mass of cold bread, w_B-loss of mass in the course of baking (%), w_C-loss of mass during cooling of bread (%).

Some of dividing machines work on the volume principle. Then the pieces of dough with the same volume have the same mass if their density is constant during dividing. However, it varies with moisture content, the fermentation stage, the level of dough in dividing machine and the pressure on the dough. According to *Zverova* et al.,[2] the necessary mass of dough depends not only on correct dividing but also on fluctuation of loss of mass during baking and cooling.

The purpose of this study was to find a direct mathematical relation for determination of necessary mass of dough for obtaining bread with defined mass, from different types of flour.

Experimental

Bread was obtained from four types of flour: T-400, T-500, T-850 and T-1000. Separately, every type of flour, baker's yeast, common salt and adequate quantity of water (water absorption according to the farinogram), and additives (Table 1), were mixed (8 min) and fermented (20 min at 28 °C). Then the dough was manually divided in pieces with mass of 650, 700, 750, 800, 900 and 1000 g. They were

Table 1 — *Recipes for kneading of dough of various types of flour*

Tablica 1 — *Recepture za miješanje tijesta od različitih tipova brašna*

Components Sastojci	Fraction related to flour Udjel u odnosu na brašno (%)
Wheat flour of type: T—400,T—500,T—850,T—1000 Pšenično brašno tip: T—400, T—500,T—850,T—1000	
Water Voda	51.43 — 60.00
Bakers´s yeast Kvasac	3.00 — 3.42
Salt Sol	1.00 — 1.14
Additives Aditivi	1.11 — 1.43

left for fermentation (45 min at 30 °C with 80 % relative humidity) and baked for 30 min at 320-220 °C at the same place in belt oven.

Immediately after baking and after 3 h of storage the mass of the bread was weighed. In some bread samples the changes of mass was followed in the course of 6 h. All experiments were carried out three times. The moisture of the dough and the crumb were determined by gravimetric method.[3]

Results and discussion

Loss of mass during baking and storage

The mass of divided pieces of dough from various types of flour and the mass of the breads, measured immediately after baking and after 3 h of storage, as well as the total loss of mass during baking and storage, are presented at the Table 2.

Table 2 — *Loss of mass in the course of baking and 3 h storage of bread prepared from various types of wheat flours*

Tablica 2 — *Gubici mase tijekom pečenja i 3 satnog skladištenja kruha pripremljenog od različitih tipova pšeničnih brašna*

Variables Varijable	Mass of dough (m_D) Masa tijesta (g)					
Flour of type T- 400 Brašno tip T- 400	650	700	750	800	900	1000
	moisture of the dough vlaga tijesta 43.6 %					
Mass of baked bread g Masa kruha nakon pečenja g	590.8	633.0	681.1	731.6	830.9	921.9
Loss of mass during baking g Gubici mase tijekom pečenja g	59.2	67.0	68.9	68.4	69.1	78.1
Loss of mass during baking, $w_{BK,}$ (%) Gubici mase tijekom pečenja (%)	9.1	9.6	9.2	8.6	7.7	7.8
Mass of 3 h stored bread, m_{CB}, (g) Masa kruha nakon 3-satnog skladištenja (g)	575.8	616.0	664.9	714.8	809.0	899.6
Loss of mass (baking + 3 h storage) (g) Gubici mase (pečenje+3 h skladiš.)(g)	74.2	84.0	85.1	85.2	91.0	100.4
Loss of mass (baking + 3 h storage) (%) Gubici mase(pečenje+3 h skladiš.)(%)	11.4	12.0	11.4	10.7	10.1	10.0
Moisture of bread after 3 h storage (%) Vlaga kruha nakon 3-satnog skladištenja (%)	43.4	43.2	44.5	43.8	43.9	44.2
Flour of type T-500	**Moisture of the dough 42.8 %**					
Mass of baked bread (g)	572.3	627.0	672.1	720.6	806.9	902.4
Loss of mass during baking (g)	77.7	73.0	77.9	79.4	93.1	97.6
Loss of mass during baking, w_{BK}, (%)	11.9	10.4	10.4	9.9	10.3	9.8
Mass of 3 h stored bread, m_{CB}, (g)	561.3	613.7	658.2	705.9	788.0	883.2
Loss of mass (baking + 3 h storage) (g)	88.7	86.3	91.8	94.1	112.0	116.8
Loss of mass (baking + 3 h storage) (%)	13.7	12.3	12.2	11.8	12.4	11.7
Moisture of bread after 3 h storage (%)	44.6	44.9	44.8	44.7	45.1	45.6
Flour of type T- 850	**Moisture of the dough 44.2 %**					
Mass of baked bread (g)	538.8	630.8	676.8	724.4	822.8	923.8
Loss of mass during baking (g)	66.2	69.2	73.2	75.6	77.2	76.2
Loss of mass during baking, w_{BK}, (%)	10.2	9.9	9.8	9.1	8.6	7.6

Variables Varijable	Mass of dough (m_D) Masa tijesta (g)					
Flour of type T- 400 Brašno tip T- 400	650	700	750	800	900	1000
	moisture of the dough vlaga tijesta 43.6 %					
Mass of 3 h stored bread, $m_{CB,}$ (g)	571.5	615.9	661.1	708.6	801.9	900.5
Loss of mass (baking + 3 h storage) (g)	78.5	84.1	88.9	91.4	98.1	99.5
Loss of mass (baking + 3 h storage) (%)	12.1	12.0	11.9	11.4	10.9	9.9
Moisture of bread after 3 h storage (%)	43.9	43.7	43.9	44.0	44.5	45.9
Flour of type T-1000	**Moisture of the dough 45.6 %**					
Mass of baked bread (g)	-	631.2	678.9	723.8	822.8	920.6
Loss of mass during baking (g)	-	68.2	71.1	76.2	77.2	79.4
Loss of mass during baking , w_{BK}, (%)	-	9.7	9.5	9.5	8.6	7.9
Mass of 3 h stored bread, m_{CB}, (g)	-	619.4	666.3	714.9	811.5	909.8
Loss of mass (baking + 3 h storage) (g)	-	80.6	83.7	85.1	88.5	90.2
Loss of mass (baking + 3 h storage) (%)	-	11.5	11.2	10.6	9.8	9.0
Moisture of bread after 3 h storage (%)	-	44.6	45.0	45.5	46.0	46.7

[a] All presented results are mean of the values of three indepenent experiments
[a] Svi prezentirani rezultati su srednje vrijednosti tri neovisnih eksperimenata

During baking the dough of 650 g prepared from the flour type T-400, and after 3 h storage (cooling) of the bread, only 74.2 g of the mass was lost. An increase in the mass of dough results in an increase in the loss of mass attaining up to 100.4 g for the dough of 1000 g. This observation is related with free surface of dough through which the moisture and the other volatile compounds evaporate. When dough was prepared of the flour type T-500 these losses varied from 88.7 g to 116.8 g, respectively. According to *Auerman,*[4] around 98 % of the total loss of mass during baking and storage is water, which quantity depends of the type of flour. The dough prepared of so called "black" types of flour have a higher level of moisture as a consequence of a greater water absorption capacity.[5] The dough of different types of flour also differ in porosity, namely the structure of the pores, through which the moisture is transported. Migration of the moisture is more difficult in the dough prepared of a black types of flour, as a consequence of the rules of molar and molecular transport.[6] Because of that the loss of mass in the course of baking and storage of the bread prepared of the flours type T-850 and T-1000, was the less. In the case of flour type T-850, it varied from 78.5 g to only 99.5 g, when mass of dough was of 650 g and 1000 g, respectively. These losses evidently were less than when flour type T-500 was used. A still less losses were observed when dough was prepared of flour type T-1000 (80.6 g of dough with mass of 700 g and 90.2 g of dough with mass of 1000 g).

The loss of mass, expressed in percents, indicates a decrease with an increase of the mass of dough, independently of type of flour. It is occured because the differences between the loss of mass during baking and 3 hours storage of breads prepared of dough which mass increased, 700 g and 650 g, 750 g and 700 g etc., are less than the differences between the mass of the dough. On that way the progressive increase of the loss of masses attained only 9.6 g (from 80.6 g to 90.2 g) for the bread of the dough of type T-1000, to 28.1 g (from 88.7 g to 116.8 g)) for the bread prepared of the dough of type T-500, while the progressive increase of the mass of dough were 300 g (from 700 g to 1000 g) for the dough of flour type T-1000, and 350 g (from 650 g to 1000 g) for the dough of the all other types of flour. Thus, although the losses of the masses are increased their ratio to the masses of the dough (which are much more increased) is decreased.

The moisture fraction in the crumbs was in the range of prescribed values by Regulations[1] (< 46 % for the bread of flour type T-500 and T-800, and < 47 for the bread of flour type T-1000).

Mathematical relation between mass of dough and mass of bread

Instead, to use the percents of mass lost in the course of baking and storage (cooling) of bread for determination of necessary mass of dough according to Equation 1, an attempt was made to find direct relation between mass of dough and mass of bread.

The masses of divided dough were fitted with the masses of correspond obtained bread after 3 h of storage, Fig. 1. A strong linear correlation was observed between mass of dough and mass of bread after 3 h of storage.

Quantitative connection of the mass of bread after 3 h of storage and mass of the dough was obtained by solving the equation of the first order by the method of the least squares (Equation 2).

$$m_D = a + b\, m_{CB\ (3\ h\ storage)} \qquad (2)$$

The values of factor *a* and *b*, coefficients of correlation and standard errors of estimation for a bread obtained of *a* different types of flour, are given in the Table 3.

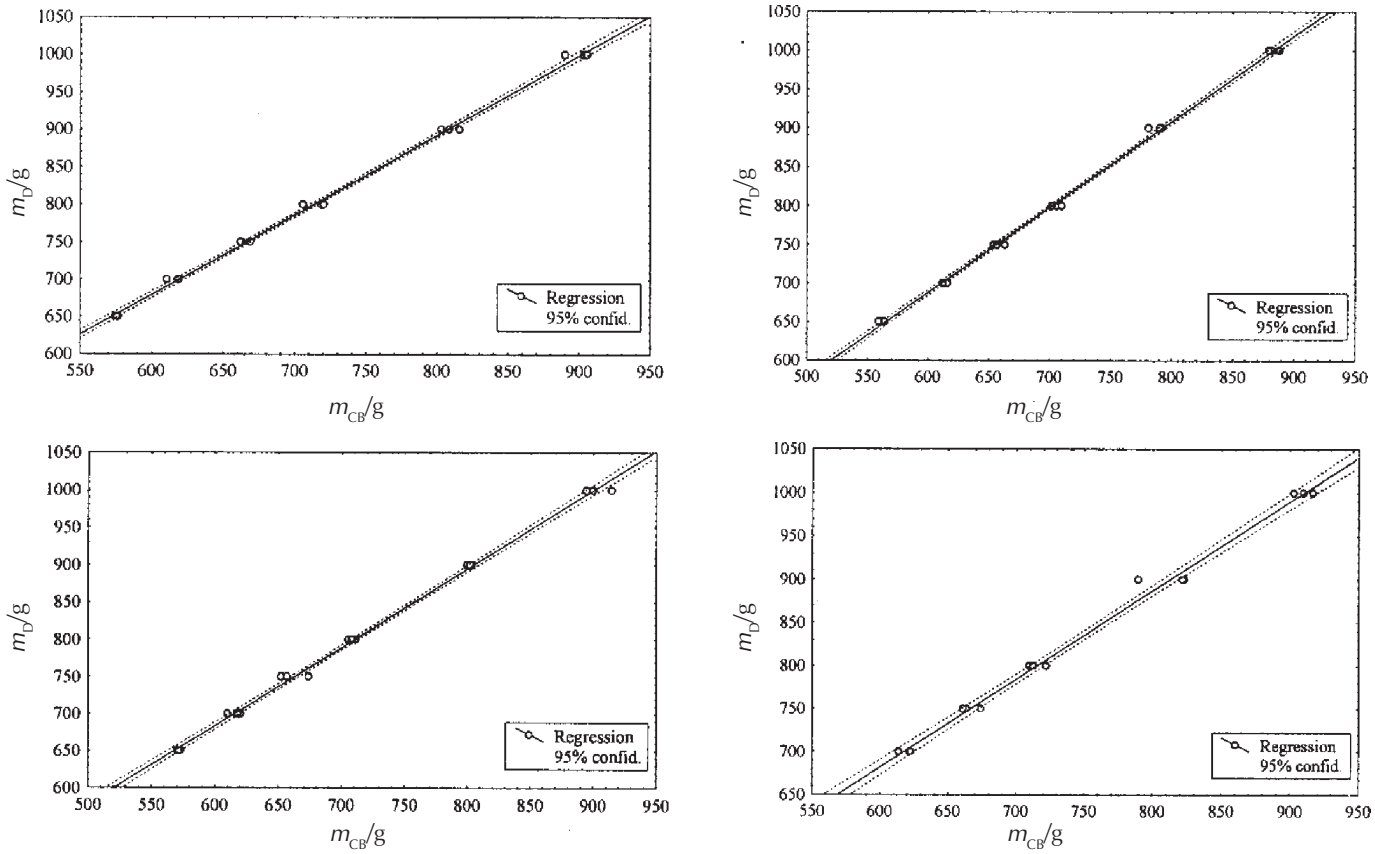

Fig.1 — *Correlation between the mass of dough m_D and the mass of bread after 3 h of storage, m_{CB}, obtained from different types of flour (for the flour T-400, R^2 = 0.998, for T-500, and T-850 R^2 = 0.999 and for T-1000 R^2 = 0.997)*

Slika 1 — *Korelacija između mase tijesta m_D i mase kruha nakon 3 sata skladištenja, m_{CB}, dobivenog od različitih tipova brašna (za brašno tip T-400, R^2 = 0.998, za T-500 i T-850 R^2 = 0.999 i za T-1000 R^2 = 0.997)*

Table 3 — *Characteristics of Equation 2 for different types of flour*

Tablica 3 — *Karakteristike jednadžbe 2 za različe tipove brašna*

Type of flour Tip brašna	T- 400	T- 500	T- 850	T-1000
Factors				
a	38.6325	25.7636	45.1839	61.786
b	1.06731	1.10335	1.06325	1.0320
Coefficients of correlation				
Koeficijenti korelacije	0.99980	0.99952	0.99985	0.99997
Standard error of estimation				
Standardna pogreška proračuna	3.024	4.499	2.518	0.931

By dissolving of Equations 2 for the used four types of flour a summary relation was obtained:

$$m_D = 45.654 + 1.0624\ m_{CB\ (3\ h\ storage)} \quad (3)$$

coefficient of correlation = 0.998311
standard error = 7.132

The differences between the necessary mass of dough estimated according Eq. 2 and 3 are in the range of 0.02 to 1.7 %, Table 4. The differences between mass of bread calculated according to Eq. 3 and mass obtained by experimental way (results of Table 2) are in the range of 0 % to 2.1 % , Table 5.

These deviations are not higher than 5 %, which one is a permitted deviation among the loafs taken in consideration in Regulations. Because of that relation (3) was assumed for determination of necessary mass of dough for obtaining bread with defined mass.

Verification of determined mathematical relation in industrial process

Validity of determined mathematical relation (3) was verified by following the mass of divided pieces of dough and the mass of breads of flour type T-500 with mass of 600 g, in industrial process, which used dividing machine on volume principle. In the period of 10 days the mass of some divided pieces of dough on dividing machine were measured, marked, and let in production process. After baking and 3 h of storage the mass of the breads obtained of the marked loafs were determined. The measured mass together with expected mass, calculated by Eq. 3 and the differences between them are presented at the Table 6.

Table 4 — *Mass of dough estimated according to equation 2 and 3 necessary for obtaining bread with defined mass*

Tablica 4 — Masa tijesta proračunata jednadžbama 2 i 3, nužna za dobivanje kruha definirane mase

Mass of bread after 3 h of storage, m_{CB} Masa kruha nakon 3 h skladištenja Δ = (| Eq3 - Eq2| / Eq2)100	500 (g)	Δ_{3-2} (%)	600 (g)	Δ_{3-2} (%)	700 (g)	Δ_{3-2} (%)	800 (g)	Δ_{3-2} (%)	900 (g)	Δ_{3-2} (%)
Mass of dough estimated acc. of equation (2) Masa tijesta prema jednadžbi (2)										
— flour of type T- 400	572.3	0.8	679.0	0.6	785.7	0.5	892.5	0.4	999.2	0.03
— flour of type T- 500	577.4	0.1	687.8	0.7	798.1	1.1	908.4	1.4	1018.6	1.7
— flour of type T- 850	576.8	0.02	683.2	0.02	789.5	0.03	895.8	0.02	1002.1	0.03
— flour of type T-1000	577.8	0.2	681.0	0.3	784.2	0.7	887.5	0.9	990.6	1.1
Mass of dough estimated acc. of equation (3) Masa tijesta prema jednadžbi (3)	576.9		683.1		789.3		895.6		1001.8	

Table 5 — *Differences between the mass of bread calculated according of Eq. (3) and real mass, obtained on experimental way*

Tablica 5 — *Razlike između mase tijesta proračunate jednadžbom 3 i realne mase dobivene eksperimentalnim putem*

Variables Promjenljive	Mass of dough Masa tijesta (g)					
	650	700	750	800	900	1000
Mass of bread acc. Eq. 3 Masa kruha prema jednadžbi 3 (g)	568.8	615.9	663.0	710.0	804.2	898.3
Deviation between real mass of bread * (Tab. 2) and estimated acc. Eq. 3 (%) Devijacija između realne mase kruha (Tab. 2) i proračunate jednadžbom 3 (%)						
— of flour of type T- 400	1.2	0.02	0.3	0.7	0.6	0.1
— of flour of type T- 500	1.3	0.4	0.7	0.6	2.1	1.7
— of flour of type T- 850	0.6	0.0	0.3	0.2	0.3	0.2
— of flour of type T- 1000	-	0.6	0.5	0.7	0.9	1.3

* after 3 h of storage, G_{CB}/
nakon 3 h skladištenja, m_{CB}

The mass of dough in industrial process varied from 668.9 g (batch VIII) to 740.7g (batch VI). The breads obtained of these pieces of dough, after 3 h of storage were 567 g and 636.2 g. Their mass acc. Eq. 3 need to be 586.6 g which means deviated 3.5 % and 654.2 g which means deviated 2.8 %, respectively. The differences between real mass of the breads obtained in the industrial process and calculated (predicted) mass of the loafs varied in the range of 1 % to almost 3.8 %.

Great differences were observed among the mass of the dough divided in a different batch of kneading, but also, although less, among the pieces of dough of the same kneaded batch, but divided in a different intervals of time. Dividing of the dough based on volume principle (which takes around 15 min) and fermentation which occurred in that time are a partially responsible for variations in mass of divided pieces of dough. Among the pieces of dough in the same batch, maximal variation in mass of 2.9 % was observed in the batch IX (min. mass of 682.2 g and max. mass of 702.2 g). Unadequate set of measure on dividing machine for dividing a defined mass of dough results in variation from 668.9 g (batch VIII) to 740.7 g (batch VI) among the pieces of different batches. This large variation (~10 %) imposed a more frequently control of divided mass of dough pieces and correction of dividing machine. Among the breads obtained from the same mass of dough, variations were observed also seen (batch VIII and X). They reached to 1.5 %.

Table 6 — *Mass of dough divided on dividing machine in different batch and the differences between the mass of bread after 3 hours of storage and mass of bread estimated acc. Eq. 3*

Tablica 6 — *Masa tijesta podijeljenog na dijelilici u različite šarže i razlike između mase kruha nakon 3-satnog skladištenja i mase kruha proračunate jednadžbom 3*

Batch Šarža	Mass Masa	Δ_{B-3} (%)		Δ_{B-3} (%)		Δ_{B-3} (%)		Δ_{B-3} (%)		Δ_{B-3} (%)	
I	— of dough, m_D, — tijesta, g	702.8		698.6		694.7		708.3		710.8	
	— of bread[a], m_{CB} g — kruha	605.3		598.0		592.1		611.4		606.1	
	— of bread acc. Eq. 3 g — kruha prema jed. (3) g	616.5	2.1	614.6	2.8	610.0	3.2	623.7	2.0	626.1	3.3
II	— of dough g	727.3		724.0		733.2		734.8		727.8	
	— of bread (g)	625.0		623.8		629.8		635.3		627.9	
	— of bread acc. Eq. 3 g	641.6	2.7	638.5	2.4	647.2	2.8	648.7	2.1	642.1	2.3
III	— of dough g	716.0		714.9		710.5		723.9		718.3	
	— of bread g	623.0		618.4		619.2		622.0		620.2	
	— of bread acc. Eq. 3 g	631.0	1.3	629.9	1.9	625.8	1.1	638.4	2.6	633.1	2.1
IV	— o f dough g	733.9		727.6		729.8		727.9		734.0	
	— of bread g	633.1		636.3		631.0		632.0		638.4	
	— of bread acc. Eq. 3 g	647.8	2.3	641.9	0.9	644.0	2.1	642.2	1.6	647.9	1.5
V	— o f dough g	731.4		720.8		722.5		728.9		737.3	
	— of bread g	634.3		618.8		625.6		629.6		636.0	
	— of bread acc. Eq. 3 g	645.5	1.8	635.5	2.7	637.1	1.8	643.1	2.1	651.0	2.4
VI	— o f dough g	730.3		734.3		737.9		740.7		729.3	
	— of bread g	624.3		629.5		638.0		636.2		638.3	
	— of bread acc. Eq. 3 g	644.4	3.2	648.2	3.0	651.6	2.1	654.2	2.8	643.5	2.4
VII	— o f dough g	709.0		705.5		713.2		694.3		705.5	
	— of bread g	608.3		609.0		618.4		598.9		609.0	
	— of bread acc. Eq. 3 g	624.4	2.6	621.1	2.0	628.5	1.6	610.5	1.9	621.1	2.0
VIII	— o f dough g	669.6		669.6		677.1		668.9		673.3	
	— of bread g	578.8		576.7		575.7		567.0		577.0	
	— of bread acc. Eq. 3 g	587.3	1.5	587.3	1.8	594.4	3.2	586.6	3.5	591.0	2.4
IX	— o f dough g	691.8		702.2		697.6		699.6		682.2	
	— of bread g	599.2		608.9		603.3		604.9		589.5	
	— of bread acc. Eq. 3 g	608.2	1.5	618.0		613.6	1.7	615.5	1.8	599.2	1.6
X	— o f dough g	708.3		705.2		705.2		704.2		711.1	
	— of bread g	600.8		605.6		604.7		601.2		613.5	
	— of bread acc. Eq. 3 g	623.7	3.8	620.8	2.5	620.8	2.7	619.8	3.1	626.4	2.1

[a] — after 3 h of storage
[a] — nakon 3 sati skladištenja
Δ_{B-3} — differences between mass of bread after 3 h of storage and mass of bread acc. Eq. 3 (%)
Δ_{B-3} — razlike između mase kruha nakon 3 h skladištenja i mase kruha prema jedn. 3 (%)

Loss of mass of bread in the course of storage

Equation 3 was based on the mass of bread after 3 hours of storage. Although bread was obtained from dough with different mass (600, 700, 750, 800, 900 and 1000 g of flour type T-500) the greatest changes in the mass of bread during storage are happened in the first hour, Fig. 2. In the period of 3 h the loss of mass was around 2 to 2.3 %. In the next three hours the changes of the mass are almost linear and much more less than 1 %.

According, this the time of 3 h assumed for calculation of the Eq. (3) is the time of the greatest changes of mass of bread in the course of storage while the next time doesn't influence too much.

Conclusion

Equation of first order was established as quantity relation between mass of dough and mass of bread after 3 hours of storage (the period of the greatest changes of the mass of bread in the course of storage). Validity of the mathematical relation was confirmed by comparison of the mass of bread of 600 g of flour type T-500 obtained in industrial process and expected mass according to the proposed equa-

tion. The maximal differences of 3.8 % was found between the real and calculated (acc. Eq. 3) mass of loafs. This maximal variation is less than alloed 5 % byregulations. The sum of this maximal variation and the maximal variation of 1.5 % found among the breads obtained from the same mass of dough in industrial process is 5.3 %. This value is still very close to the allowed regulatives. Because of that determined mathematical relation could be assumed as valid for determination of necessary mass of dough for obtaining bread of different types of flour with defined mass.

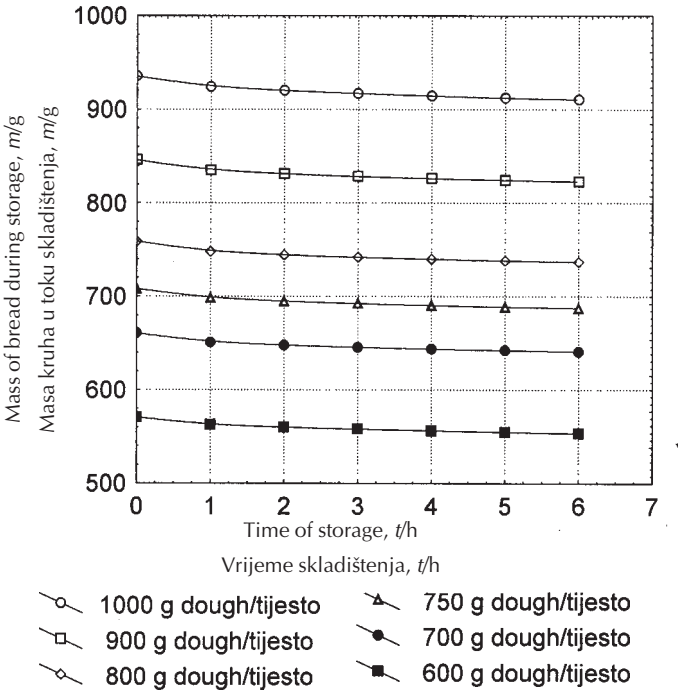

Fig. 2 — *Changes in mass of bread produced from dough of different mass (of flour of type T-500) in the course of 6 h of storage*

Slika 2 — *Promjena mase kruha dobivenog od tijesta različite mase (od brašna tipa T-500) tijekom 6-satnog skladištenja*

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Symbols
Simboli

- ^{a} - factor
  - faktor
- ^{b} - factor
  - faktor
- m - mass, g
  - masa, g
- R^2 - coefficient of correlation
  koeficijent korelacije
- w - mass fraction, %
  - maseni udjel, %

SAŽETAK

Utvrđivnje matematičke relacije za određivanje potrebne mase tijesta za dobivanje kruha s definiranom masom

M. Bocevska, T. Dimeski i I. Aldabas*

Pripremljen je kruh od različitih tipova brašna: T-400, T-500, T-850 i T-1000. Zamiješeno tijesto podijeljeno je na komade s masom od 650, 700, 750, 800, 900 i 1000 g. Tijekom pečenja i skladištenja kruha utvrđena je razina gubitka mase s povećanjem mase tijesta, neovisno o tipu upotrijebljenog brašna. Međutim gubici mase opadaju s uzlaznim brojem tipa brašna kod tijesta s istom masom. Između mase tijesta i mase kruha nakon trosatnog skladištenja utvrđena je stroga linearna korelacija (R^2=0,99). Kvantitativna veza između mase kruha i potrebne mase tijesta utvrđena je kao jednadžba prvog reda, m_{Tijesto} = 45,654 + 1,0624 $m_{\text{Hladan kruh (3 sata skladištenja)}}$. Njezina je validnost provjerena i potvrđena praćenjem mase tijesta i kruha od 600 g brašna T-500 u industrijskoj proizvodnji.

Fakultet tehnologije i metalurgije,
Sveučilište "Sv. Kirila i Metodija"
Ruđer Bošković 16, P.P. 580, 1000 Skopje, Makedonija

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