GIDA (2011) 36 (2): 77-82 *Research* / Araştırma

EFFECTS OF SOME HYDROCOLLOIDS AND SURFACTANT ON THE RHEOLOGICAL PROPERTIES OF HARD WHEAT FLOUR DOUGH BY USING RESPONSE SURFACE METHODOLOGY

Basak Sungur[1,], Recai Ercan[2]**

[1]Ankara University, Kalecik Vocational School Food Technology Program, Ankara - Turkey
[2]Ankara University, Faculty of Engineering, Department of Food Engineering, Ankara - Turkey

Received / Geliş tarihi: 23.12.2010
Received in revised form / Düzeltilerek geliş tarihi: 28.02.2011
Accepted / Kabul tarihi: 03.03.2011

Abstract

The aim of this study was to determine the effect of three hydrocolloids (guar gum, carboxymethylcellulose (CMC) and locust bean gum (LBG)) and diacetyl tartaric acid ester of mono-diglycerides (DATEM) on the rheological properties of hard wheat flour dough by using response surface methodology. Each independent variable was tested at five levels: guar gum, CMC and LBG were 0.00%, 50%, 1.00%, 1.50% and 2.0% (w/w, on weight of flour basis), and DATEM was 0.00%, 0.25%, 0.50%, 0.75% and 1.00% (w/w, on weight of flour basis). The results showed that the guar gum was the most effective additive on water absorption values and the maximum resistance of the dough to stretching out. The best results among the combinations were generally obtained with CMC and DATEM on the maximum resistance of the dough to stretching out.

Keywords: Hydrocolloids, rheological properties, surfactants, response surface methodology (RSM).

YÜZEY TEPKİ METODU KULLANILARAK BAZI HİDROKOLLOİDLER ve YÜZEY AKTİF MADDENİN SERT BUĞDAY UNU HAMURUNUN REOLOJİK ÖZELLİKLERİ ÜZERİNE ETKİLERİ

Özet

Bu çalışmanın amacı üç hidrokolloidin (guar gam, karboksimetilselülоz (CMC) ve keçiboynuzu gamı LBG) ile mono-digliseridlerin diasetil tartarik asit esterlerinin (DATEM) sert buğday unu hamurunun reolojik özellikleri üzerine etkilerini yüzey tepki metodu (RSM) kullanarak belirlemektir. Her bir bağımsız değişken 5 farklı oranda test edilmiştir; guar gam, CMC ve LBG, %0.00, %0.50, %1.00, %1.50 ve %2.0 (w/w un ağırlığı üzerinden), DATEM, %0.00, %.0.25, %0.50, %0.75 ve %1.00 (w/w un ağırlığı üzerinden). Elde edilen sonuçlara göre hamurun uzamaya karşı gösterdiği maksimum direnç ile su absorpsiyonu değerleri üzerine en önemli etkiyi guar gam göstermiştir. Kombinasyonlar arasında hamurun uzamaya karşı gösterdiği direnç üzerine genel olarak en olumlu etkiyi CMC ve DATEM göstermiştir.

Anahtar kelimeler: Hidrokolloidler, reolojik özellikler, yüzey aktif maddeler, yüzey tepki metodu (RSM).

This study is a part of Ph Thesis of Basak Sungur / Bu çalışma Başak Sungur'un Doktora tezinin bir bölümüdür.

** *Corresponding author* / Yazışmalardan sorumlu yazar ;
sungur@ankara.edu.tr ✆ (+90) 312 857 1394 / 131 (+90) 312 857 0333

INTRODUCTION

Nowadays, additives are extensively used in the baking industry for several reasons such as improving bread quality, enhancing nutritional value, retarding staling and preventing it from spoiling. Some additives have focused on improving rheological characteristics of dough and bread quality, such as hydrocolloids (1-3), others on dough modifiers, shortening sparing agents as anti-staling agents, and as improvers for the production of high-protein breads, such as different emulsifiers like DATEM (4). Therefore, the bakery industry has increasingly exploited the applications of hydrocolloids and emulsifiers (3, 4).

Hydrocolloids, known as water-soluble gums, have specifically found a wide application such as: thickening, gel formation, melting, gelatinization, fragmentation and retrogradation of starch, foam stabilization and increasing water-holding capacity (5-7).

Hydrocolloids have been employed to modify dough and improve bread making quality (8, 9). The functional effects of hydrocolloid stem from their ability to modify dough rheology and keeping qualities of finished baked products (9) and they can induce structural changes in the main components of wheat flour systems during the bread making steps and bread storage (4). These additives can also be added to wheat flours in order to increase the level of water absorption of flour (10).

Shittu et. al. (9) studied the effect of xanthan gum on composite cassava-wheat dough handling properties and some bread qualities. It was found that the higher gum content increased the oven spring, loaf volume, crumb softness, percent cell area and overall sensory acceptability of composite cassava-wheat bread. Linlaud et. al. (10) also analyzed the effect of hydrocolloid addition on water absorption of flour and their influence on dough rheology. It was found that guar gum-added mixtures led to more stable dough and high-methoxyl pectin to the less stable ones.

Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving and optimizing processes. It usually contains three stages (1) design of experiments, (2) response surface modeling through regression and (3) optimization. The main advantage of RSM is the reduced number of experimental trials needed to evaluate multiple parameters and their interactions. The experimental data were utilized to build mathematical models using regression methods. Once an appropriate approximating model is obtained, this model can then be analyzed by using various optimization techniques to determine the optimum conditions for the process (11).

The aim of the recent study has been to evaluate the effects of hydrocolloids and surfactant (DATEM) on the rheological properties of dough. As a control, bread without gum and surfactant was used. An RSM study of the relative contribution of variables (guar gum, CMC, LBG and DATEM) to the rheological properties of dough was conducted as described by Box and Wilson (12).

MATERIALS AND METHODS

Basic Ingredients and Additives

A commercial blend of Turkish hard wheat flour of 13.63% moisture (13), 0.60% ash content (14), 13.64% protein (15), 453 s Falling number (16), 60.6% water absorption in farinograph (17), 770 BU maximum resistance of dough (Rm) in extensograph (18). The hydrocolloids (guar gum, CMC and LBG) included in this analysis were obtained from INCOM Incorporated Company, Mersin, Turkey, and DATEM was obtained from Additive Food, Ankara, Turkey.

Experimental Design

A central composite design was created using the software package with StatEase Design Expert 6.0.10 software package (Stat-Ease Inc., 2003, Minneapolis, USA). Five levels of each independent variable were incorporated into the design. Table 1 shows the levels of independent variables and the combination of independent variable levels used in the central composite design. The complete experimental design, four factors at five levels, required 24 + 2 x 4 + 4 = 28 formula combinations. The centre point in the design was repeated four times to calculate the reproducibility of the method.

Table 1. Central composite design showing independent variable level combinations (for guar gum, CMC and LBG -2.00: 0.00%, - 1.00:0.50%, 0.00:1.00%, + 1.00:1.50%, + 2.00:2.00%; for DATEM -2.00: 0.00%, -1.00:0.25%, 0.00:0.50%, + 1.00:0.75%, + 2.00:1.00%;)

Experiment number	Guar gum	CMC	LBG	DATEM
1	-1.00	-1.00	1.00	-1.00
2*	0.00	0.00	0.00	0.00
3*	0.00	0.00	0.00	0.00
4	1.00	1.00	1.00	-1.00
5	-1.00	-1.00	-1.00	1.00
6	-1.00	1.00	-1.00	-1.00
7	2.00	0.00	0.00	0.00
8	1.00	-1.00	-1.00	1.00
9	-1.00	-1.00	1.00	1.00
10	0.00	-2.00	0.00	0.00
11	1.00	1.00	1.00	1.00
12	1.00	-1.00	1.00	-1.00
13	1.00	-1.00	-1.00	-1.00
14	-2.00	0.00	0.00	0.00
15	1.00	1.00	-1.00	-1.00
16	-1.00	1.00	1.00	1.00
17	0.00	0.00	0.00	-2.00
18	0.00	0.00	0.00	2.00
19	0.00	0.00	2.00	0.00
20	-1.00	1.00	1.00	-1.00
21	0.00	2.00	0.00	0.00
22	1.00	1.00	-1.00	1.00
23	-1.00	-1.00	-1.00	-1.00
24	1.00	-1.00	1.00	1.00
25*	0.00	0.00	0.00	0.00
26*	0.00	0.00	0.00	0.00
27	-1.00	1.00	-1.00	1.00
28	0.00	0.00	-2.00	0.00

*: centre points

The response variables were water absorption and maximum resistance of the dough. Each of the response variables were analyzed for quadratic model.

Statistical Analysis

Table 2 shows the relationship between the independent variables (guar gum, CMC, LBG and DATEM) and the dependent variables (water absorption and maximum resistance of dough) described regression coefficient and significance of the model. A tree-dimensional response surface and contour plot were generated from the regression equation over the range of variables tested. Analyses of variance (ANOVA) were performed to determine significant differences between independent variables (P ≤ 0.05).

Table 2. Coefficient and significance of regression models for hard wheat dough formulated by flour containing different hydrocolloids and surfactant

	Water absorption (%)	Maximum resistance of the dough (Rm, BU*)
Intercept	+71.83[a]	+637.09[a]
X_1	+1.44[a]	+22.87[a]
X_2	+1.44[a]	-31.30[a]
X_3	+1.52[a]	-21.30[a]
X_4	-0.22[a]	+14.54
X_1^2	-0.13	+0.86
X_2^2	-0.13	-2.89
X_3^2	-0.13	-16.64
X_4^2	$-1.56.10^{-3}$	-5.39
X_1xX_2	-0.13	-1.74
X_1xX_3	-0.26[a]	+7.01
X_1xX_4	$-7.38.10^{-3}$	-5.49
X_2xX_3	$-7.38.10^{-3}$	+12.01
X_2xX_4	$-7.38.10^{-3}$	+22.01[a]
X_2xX_4	-0.13	+13.26
R^2	0.9901	0.7878

*: brabender units ; a: the term is significant at P ≤ 0.05 ; X1= Guar gum ; X2= CMC ; X3= LBG ; X4= DATEM

RESULTS AND DISCUSSION

Effects of Hydrocolloids and Surfactant (DATEM) on the Rheological Properties of Dough

Water Absorption (%)

As shown in Figure 1(a), (b) and (c), with the addition of hydrocolloids, the water absorption of dough significantly increased. The results of the recent study support previous reports showing that hydrocolloids increase water absorption and improve the technological properties of dough because of their hydrophilic texture (9, 19-21). On the other hand, the use of hydrophilic gums such as guar gum, LBG and CMC in the baked goods improve moisture retention (22). Increased concentration of DATEM resulted in a slight decrease in water absorption of dough (Figure 1(d)). This result is consistent with some studies on the effect of surfactants on

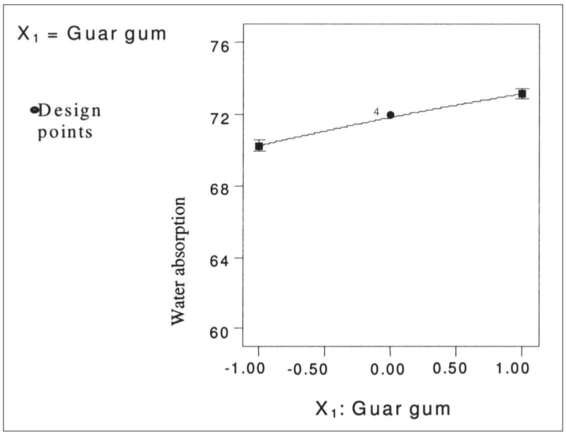

Figure 1(a)

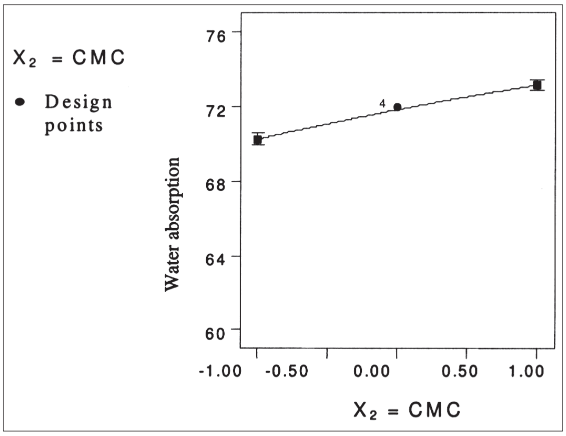

Figure 1(b)

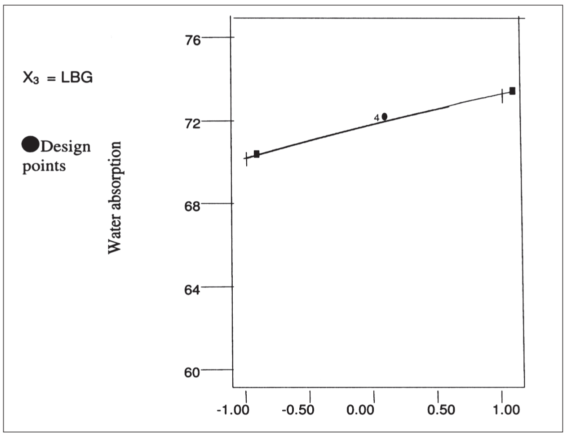

Figure 1(c)

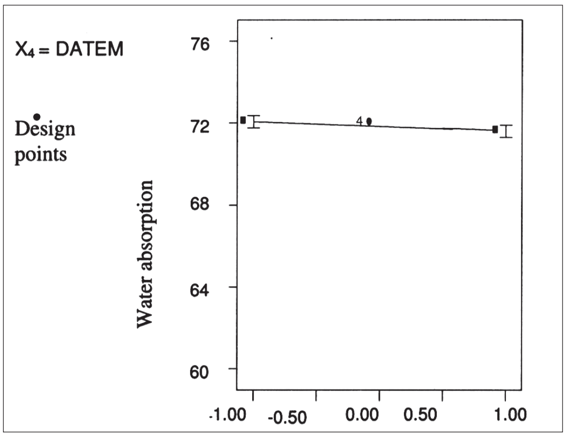

Figure 1(d)

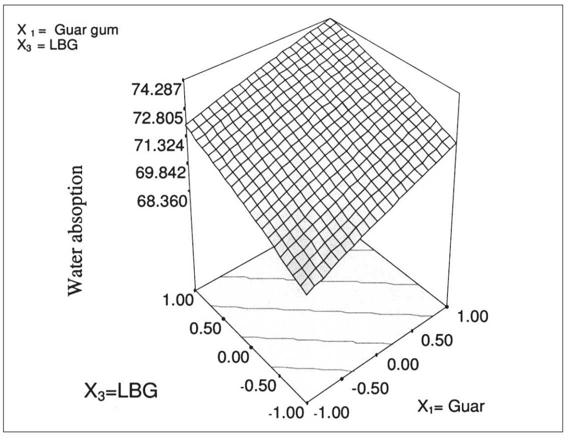

Figure 1(e)

Figure 1. Effect of hydrocolloids and surfactant on hard wheat flour's water absorption: (a) guar gum, (b) CMC, (c) LBG, (d) DATEM, (e) guar gum and LBG.

farinogram properties of dough, which show that surfactants did not affect or reduce water absorption of dough (23, 24). In combinations, guar gum and LBG caused a decrease in the water absorption for all the tested samples (Figure 1(e)). Other combinations did not have any significant effects on the variation of water absorption of dough (Table 2).

Maximum Resistance of Dough (Rm)

Increasing concentrations of guar gum caused an increase in the maximum resistance of dough (Figure 2(a)). In contrast, the addition of other hydrocolloids (CMC and LBG) decreased in the maximum resistance of dough (Figure 2(b) and (c)). DATEM did not have any significant effect on the maximum resistance of dough (Table 2).

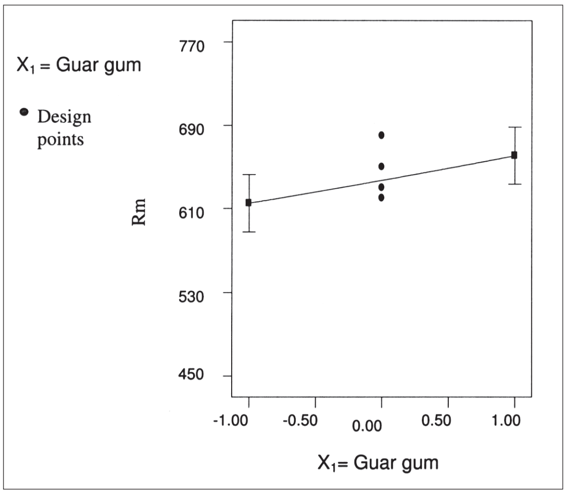

Figure 2(a)

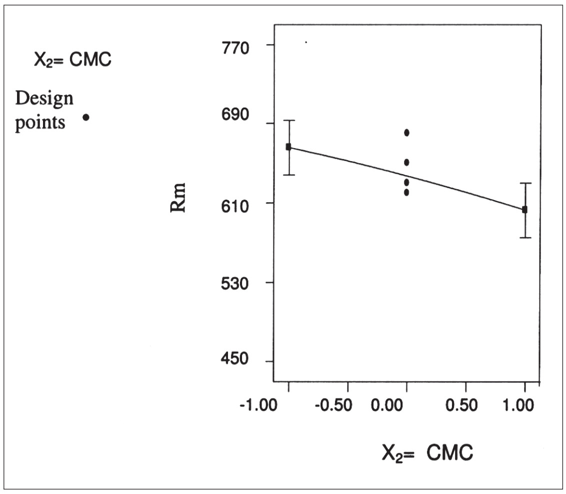

Figure 2(b)

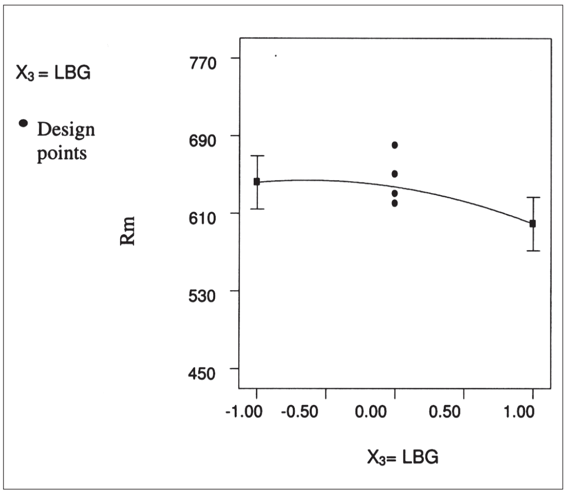

Figure 2(c)

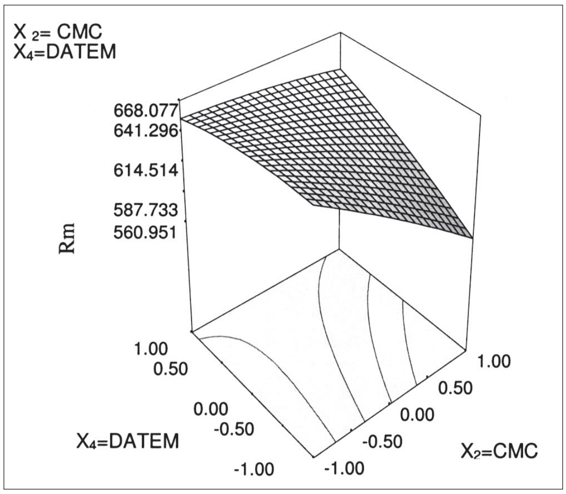

Figure 2(d)

Figure 2. Effect of hydrocolloids and surfactant on hard wheat flour dough's maximum resistance: (a) guar gum, (b) CMC, (c) LBG, (d) CMC and DATEM.

It has been known that hydrocolloids such as CMC and the other derivatives of celluloses have reduced the maximum resistance of dough (25). In combination, CMC and DATEM increased in the maximum resistance of dough, with the greatest effect among the combinations (Figure 2(d)). Mettler and Seibel (1) observed that the detrimental effects of hydrocolloids could be compensated, in part, by increasing concentrations of DATEM. Bollain and Collar (26) also indicated that DATEM has been shown to increase Rm in comparison with hydroxypropylmethylcellulose (HPMC) and high ester pectin. It has been reported that the dough strengthening effect of DATEM has been related to strong binding effects and thereby to the promotion of the development of a gluten-starch-lipid complex (27).

This study has showed that the rheological properties of hard wheat flour dough are significantly affected by hydrocolloids and DATEM. With the addition of different concentrations of guar gum, the water absorption and maximum resistance of the dough significantly increased. In combination, CMC and DATEM increased in maximum resistance of the dough, with the greatest effect among the combinations. In conclusion, hydrocolloids and DATEM can be combined, contributing to much stronger rheological properties of hard wheat dough.

REFERENCES

1. Mettler E, Seibel W. 1993. Effects of emulsifiers and hydrocolloids on whole wheat bread quality: A response surface methodology study. *Cereal Chem*, 70, 373-377.

2. Dodic J, Pejin D, Dodic S, Popov S, Mastilovic J, Popov-Raljic J, Zivanovic S. 2007. Effects of hydrophilic hydrocolloids on dough and bread performance of samples made from frozen doughs. *J Food Sci,* 72, 235-241.

3. Kohajdova Z, Karovicova J, Schmidt S. 2009. Significance of emulsifiers and hydrocolloids in bakery industry. *Acta Chimica Slovaca*, 2, 46-61.

4. Selomulyo VO, Zhou W. 2007. Frozen bread dough: effect of frerezing storage and dough improvers. *J Cereal Sci*, 45, 1-17.

5. Ward FM, Andon SA. 1993. Water- soluble gums used in snack foods and cereal products. *Cereal Foods World*, 38, 748-752.

6. Ahmed J, Ramswamy HS, Ngadi MO. 2005. Rheological characteristics of arabic gum in combination with guar and xanthan gum using response surface methodology: Effect of temperature and concentration. *Int Food Prop*, 8, 179-192.

7. Nussinovitch A. 2005. Production, properties and applications of hydrocolloid cellular solids. *Mol Nutr Food Res*, 49, 195-213.

8. Collar C, Andreu P, Martinez JC, Armero E. 1999. Optimization of hydrocolloid addition to improve wheat bread dough functionality: a response surface methodology study. *Food Hydrocolloids*, 13, 467-475.

9. Shittu TA, Aminu RA, Abulude EO. 2009. Functional effects of xanthan gum on composite cassava-wheat dough and bread. *Food Hydrocolloids*, 23, 2254-2260.

10. Linlaud NE, Puppo MC, Ferrero C. 2009. Effect of hydrocolloids on water absorption of wheat flour and farinograph and textural characteristics of dough. *Cereal Chem*, 86, 376-382.

11. Myers RH, Montgomery DC. 1995. Response surface methodology: Process and product optimization using designed experiments (1st ed.). *John Wiley and Sons*. Inc, New York: methodology. *J Food Comp Anal*, 13, 45-57.

12. Box GEP, Wilson KB. 1951. Experimental attainment of optimum conditions. *J R Stat Soc*, 13, 1–45.

13. Int Assoc Cereal Chem. ICC-Standard NO 110 / 1. Approved 1976.

14. Int Assoc Cereal Chem. ICC-Standard No 104 / 1. Approved 1990.

15. Int Assoc Cereal Chem. ICC-Standard No 105 / 2. Approved 1994.

16. Int Assoc Cereal Chem. ICC-Standard No 107 / 1. Approved 1995.

17. Int Assoc Cereal Chem. ICC-Standard No 115 / 1. Approved 1992a.

18. Int Assoc Cereal Chem. ICC-Standard No 114 / 1. Approved 1992b.

19. Guarda A, Rosell CM, Benedito C, Galotto MJ. 2004. Different hydrocolloids as bread improvers and antistaling agents. *Food Hydrocolloids*, 18, 241-247.

20. Cawley RW. 1964. The role of wheat flour pentosans in baking. II. Effect of added flour pentosans and other gums on gluten-starch loaves. *J Sci Food Agric*, 15, 834-839.

21. Lazaridou A, Duta D, Papageorgiou M, Belc N, Biliaderis CG. 2007. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten- free formulations. *J Food Eng*, 79, 1033-1047.

22. Anderson DMW, Andon SA. 1998. Water-soluble food gums and their role in product development. *Am Assoc Cereal Chem*, 33, 844-850.

23. Tsen C, Weber J. 1981. Dough properties and proof times of yeasted doughs effected by surfactants. *Cereal Chem*, 58, 180-181.

24. Knightly WH. 1988. Surfactants in baked foods: Current practise and future trends. *Cereal Foods World*, 33, 405-412.

25. Armero E, Collar C. 1996. Antistaling additives, flour type and sourdough process. Effects on functionality of wheat doughs. *J Food Sci*, 61, 299-303.

26. Bollain C, Collar C. 2004. Dough viscoelastic response of hydrocolloid/ enzyme/ surfactant blends assessed by uni- and bi- axial extension measurements. *Food Hydrocolloids*, 18, 499-507.

27. Mettler E, Seibel W, Elbaya AW, Pfeilsticker K. 1991. Experimentelle studien der emulgator- und hydrocolloidwirkungen zur optimerung der funktionellen eigenschaften von weizenbroten. 2. Mitt: Vergleichende analytische and rheologische untersuchungen der emulgator und hydrocolloid-wirkungen waehrend der teigfuehrung. *Getreide Mehl Brot*, 45, 206-210.