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ORIGINAL RESEARCH PAPER

EFFECT OF SUGAR SUBSTITUES ON WHEAT DOUGH RHEOLOGY

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Abstract: High intake of added sugars has many negative effects on human health. This is the reason why in recent years the replacement of sugar (sucrose) in food and drinks by natural and artificial sweeteners (low-calorie) has increased significantly. The sugar plays an essential role in technology of bakery and pastry products. The purpose of this article is to evaluate the effect of sugar substitutes on rheological properties of wheat dough. Erythritol and stevia (nutritious sweetener) have been used as sugar substitutes. The sugar and sweeteners were added in white wheat flour at levels of 0-5% (the rheological properties of 100 % white wheat flour was determinate for comparison). Effects were seen on the dough rheology, which were evaluated by farinographic characteristics with Brabender Farinograph-E with electronic measuring system, according to AACC No. 54-21, ICC No. 155/1. Water absorption decreased with the increase of both sweeteners ratio because the protein and complex carbohydrates contents are reduced. The dough development time varied non-significantly with addition of sweeteners (from 1.7 to 2.2% for both sweeteners, stevia and erythritol). The dough stability time increased significantly from 1.7 to 2.6 min in both cases of sweeteners adding. The degree of softening values decreased with the supplementation of both with stevia and with erythritol. The Farinograph Quality Number values increased more with stevia supplementation, from 25 to 78, and up to 43 for erytrithol added. The obtained results are important for the specialists of the bakery technological process.

Keywords: *dough, erythritol, rheological properties, stevia, sugar, sweetener*

INTRODUCTION

Sugar is one of the most consumed and popular foodstuffs in the world, including in Romania, where, according to the National Institute of Statistics, the gross average consumption in 2017 was about 25.7 kg/capita. In recent decades the consumer demand for low calorie products has increased as many diseases have been reported due to excessive consumption of sugar. For this reason, the food industry is widely using non-caloric sweeteners or sugar substitutes in foods and beverages.
The table sugar (sucrose) is considered the standard for the sweet taste it offers and is the most common sweetener in the food industry and also especially in the bakery industry [1]. The sucrose, composed of glucose and fructose, has sweetness considered to be equal to 1 and is the standard value used for measuring the sweetening power of all sweeteners. Along with the taste it offers to baked products, the sugar performs other functions such as delayed starch gelatinization and protein denaturation, gives the product a good structure, texture and flavor and contributes to the crust browning by Maillard reaction [1 – 3]. Sugar substitutes must be able to address the functions that sucrose performs in bakery products.
A sweetener (sugar substitute) is any natural or synthetic alternative substance to sugar, which offers a sweet taste to food and beverages and provides the possibility of controlling the consumption of calories, carbohydrates or sugar. Sweeteners are food additives varying in taste, level of sweetness and stability [1].
Stevia is an herb with scientific name Stevia Rebaudiana Bertoni, whose leaves contain steviol glycosides, the sweet components of these (200 - 300 times sweeter than sucrose). Steviol glycosides are extracted from de leaves with hot water and then recrystallized in a hydroalcoholic solution More than 30 different steviol glycosides are known, but the most common are stevioside (chemical formula $C_{38}H_{60}O_{18}$) and rebaudioside A (chemical formula $C_{44}H_{70}O_{23}$), which accounts for approximately 90 % of all sweet glycosides in stevia [3 – 5]. In the European Union have been approved steviol glycosides with the E 960 symbol for use in food industries as sucrose substitute. Stevia is a natural non-nutritive high intensity sweetener and is used in dairy, bakery products or as a table top sweetener.
Erythritol is a four-carbon sugar alcohol ($C_4H_{10}O_4$) or polyol with sweetening power about 0.6-0.8 of the sucrose and a very low caloric value of just 0.3 $kcal \cdot g^{-1}$. Erythritol (E 968) occurs naturally in fruits (grapes, pears, melon), in vegetables, honey and seaweeds and it is obtained by a natural fermentation process. It is an ingredient used to replace sucrose of many products like baked products (cakes, biscuits, cookies), calorie-reduced beverages, dairy products, chocolate, candies [1 – 7].
Due to their basic characteristics such as sweetness, stability in high temperature (steviol glycosides are stable in high temperature up to 200 ^{o}C), non-reducing, suitable for diabetics, tooth-friendly, stevia and erythritol have a widespread and growing interest for consumers and the food industry, which aims to reduce the intake of sugar and calories naturally without compromising the taste [3, 8, 9]. Erythritol is not an intense sweetener and it not intervenes in Maillard type browning reactions, stevia can offer sweetness to baked products, but it cannot imitate or replace sugar functions. Sweeteners are therefore used in blend with other sweeteners or bulking agents (e.g. erythritol with maltitol, acesulfame or aspartame, stevia with polydextrose) so as to obtain good-tasting and reduced-calorie products similar to those traditionally obtained

[1, 8]. Erythritol can be blended with even stevia to give a similar sweet taste to that of sucrose [8, 10].

Sugar and sugar substitutes influence the various rheological characteristics of wheat dough depending on the level and type. The effect of different type of sugars and sugars substitutes on various levels in wheat dough was examined in numerous studies [11-15]. In paper [16] the rheological properties of wheat dough were examined with different percentage of stevia extracts (0, 25, 50, 75 and 100 %) and it was found that the values for water absorption, development time and arrival time decreased in all samples, but the degree of softening has increased. In the same paper it was found that the substitution of sucrose with stevia extract up to 75 % had a very good impact on the physical quality of biscuits (volume, weight, height, and color). An addition level of about 7 % erythritol in baked products (cakes, biscuits) improves baking stability and shelf life. It is also possible to reduce the caloric content by more than 30 % without significant change in the organoleptic quality of the product. Compared to sucrose, erythritol used in bakery products gives more compact dough, a soft product and lower color intensity [8].

The rheological properties of dough describe his behavior under various processing conditions and knowledge of them is very important in selection of appropriate raw materials.

The objective of this work was to evaluate the effects of different type and levels of sugar substitutes (erythritol and stevia) on the rheological characteristics of white wheat dough.

MATERIALS AND METHODS

For the experiments were used two types of sweeteners, stevia and erythritol, purchased from a local market in Bucharest, Romania and white wheat flour provided by the Greci Mill, Ilfov, Romania. The quality indices of the wheat flour are: moisture content 12.75 %, ash 0.46 %, sedimentation index 24 mL, wet gluten 26 %, gluten deformation index 2.5 mm and falling number index 244 s. Samples were made from wheat flour supplemented with stevia and erythritol at different levels: 0 % (control sample), 1 %, 2 %, 3 %, 4 % and 5 %.

Effects of supplementation on wheat flour dough rheology were studied with Brabender Farinograph-E with electronic measuring system, according to AACC No. 54-21, ICC No. 155/1, [17]. The farinograph device is equipped with 300 g bowl capacity and the dough mixing was at the standard speed of 63 rpm at 30 ^{o}C. So, the sweeteners percentage was calculated for 300 g of wheat flour. Considering the value of water absorption of flour as being constant, the same amount of distilled water was added to each sample. The dough rheological parameters such as water absorption, dough development time, dough stability, degree of dough softening, Farinograph Quality Number were recorded and calculated from farinograms, as in the example in Figure 1.

Dough is appreciated by its consistency, which is a complex rheological property, resulting from combined effect of the basic properties of viscosity, plasticity, elasticity. The consistency of the dough is conventionally quantified by Brabender units (1 BU ≈ 10-3 daN·m). It is considered that the dough has a normal consistency when kneading requires a maximum moment of 500 BU. Water absorption is the percentage of water in the flour from standard consistency dough (500 BU). The dough development time is the time it takes for it to form and reach at a normal consistency of 500 BU. Stability time is an indicator of dough strength and represent the period in which the dough maintains its normal consistency with the continuation of the mixing process.

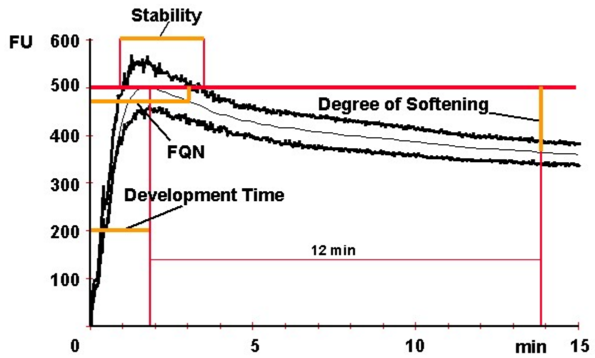

Figure 1. *Example of a farinograph curve and how to interpret it [18]*

Degree of dough softening is a measure of its degradation and is expressed by the difference between the standard consistency (500 BU) and the consistency that touch the curve after 12 minutes of mixing after achieving standard consistency. Farinograph Quality Number (FQN) is an empirical flour quality index based on a logarithmic function that expresses a combination of the above characteristics through a number between 0-100. As the value of this number is higher, the flour is considered to be stronger. Therefore, this farinograph characteristic could establish the quality of flour: weak flour or strong flour.

For farinograph parameters one determination for each sample was made. The processing of experimental data was performed using the application package MS Office Excel.

RESULTS AND DISCUSSION

Data of rheological parameters of all dough samples are presented in Table 1. The variation of these parameters is shown in Figure 2.

Table 1. *Values of rheological parameters*

Samples	Water absorption [%] /Correction for 500 [BU]	Consistency [BU] (for water absorption of 58.3%)	Dough development time [min]	Dough Stability [min]	Degree of softening (10 min after test starting) [BU]	Farinograph Quality Number
Sweetener 0%	58.3	550	1.7	1.7	135	25
Stevia 1%	56.4	474	1.7	2.0	103	29
Stevia 2%	55.1	425	2	2.2	76	37
Stevia 3%	54.9	416	2	2.3	61	40
Stevia 4%	53.8	373	2	2.4	52	44
Stevia 5%	52.8	330	2.2	2.6	32	78
Erythritol 1%	57.5	521	1.7	1.6	121	25
Erythritol 2%	57.1	502	1.7	1.5	119	26
Erythritol 3%	55.0	418	1.9	2.1	72	34
Erythritol 4%	54.8	412	1.9	2.2	73	34
Erythritol 5%	54.2	388	2.2	2.6	57	43

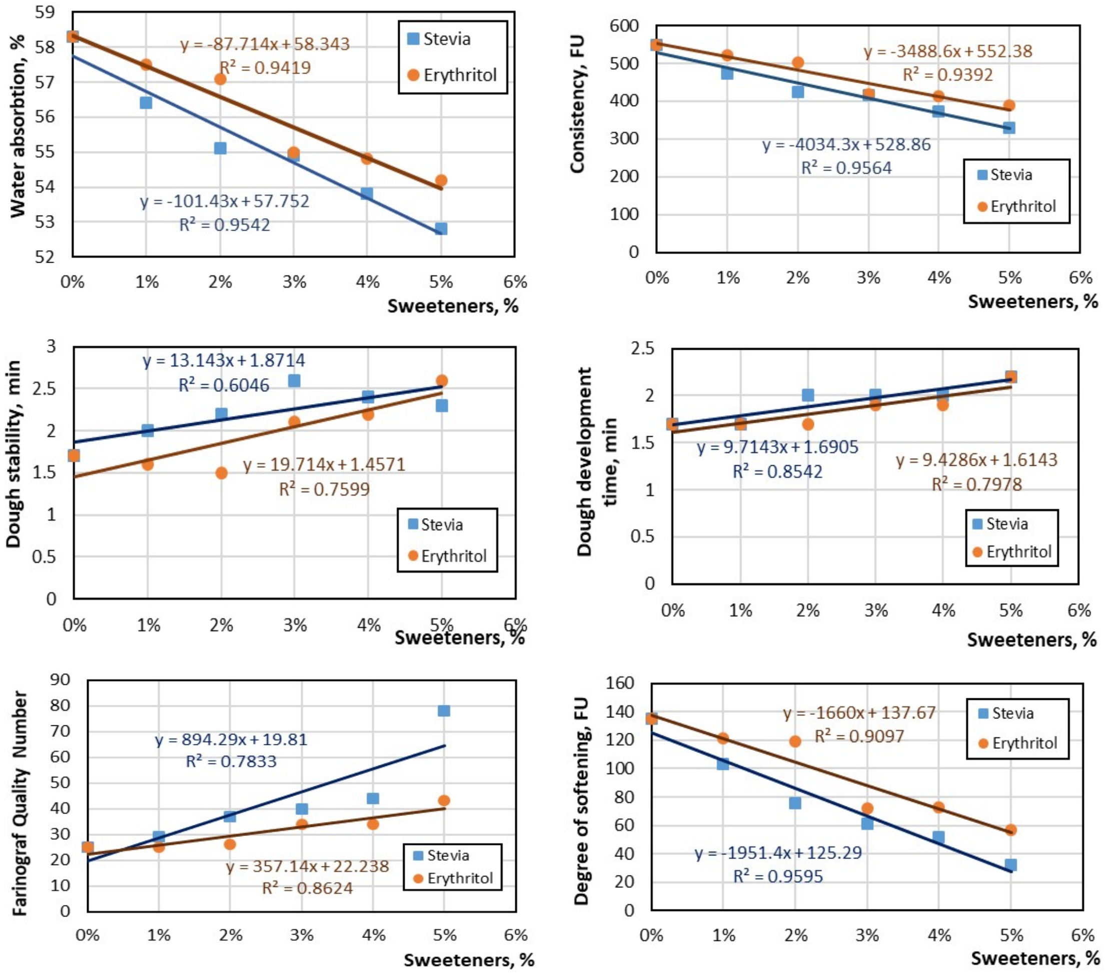

***Figure 2.** Variation of farinograph parameters with level and type of sweeteners*

Analyzing the graphs in Figure 2 it can be observed that we have the highest linear correlation for water absorption, consistency and degree of softening, where the values for R^2 correlation coefficient are high, $R^2 > 0.909$. On the other hand, for dough stability, dough development time and Farinograph Quality Number the values for R^2 correlation coefficient are lower, from 0.604 to 0.864. As the results show, the water absorption (%) has decreased, depending on the increase in the level of both types of sweeteners. Water absorption ranged from 58.3 % (control sample) to 52.8 % for sample with 5 % stevia and to 54.2 % for sample with 5 % erythritol. Water absorption had a larger decrease in stevia added samples (about 9.43 %) compared to the added erythritol samples (about 7.03 %). With the increase in the sweetener level, the water absorption was reduced compared to the control sample, which means that a larger amount of sweetener requires more water to make the dough reach the standard consistency (500 BU). It is known that during the kneading process the proteins are hydrated to form the gluten. So, the main component responsible for wheat flour water absorption is gluten. The decrease of water absorption can be explained by the fact that the protein content and the complex carbohydrates are reduced with the increase in the level of sweeteners. Similar results were noticed in paper [16], where was used stevia extracts (stevioside). In Figure 3 are presented the farinograph curves obtained from experimental determinations.

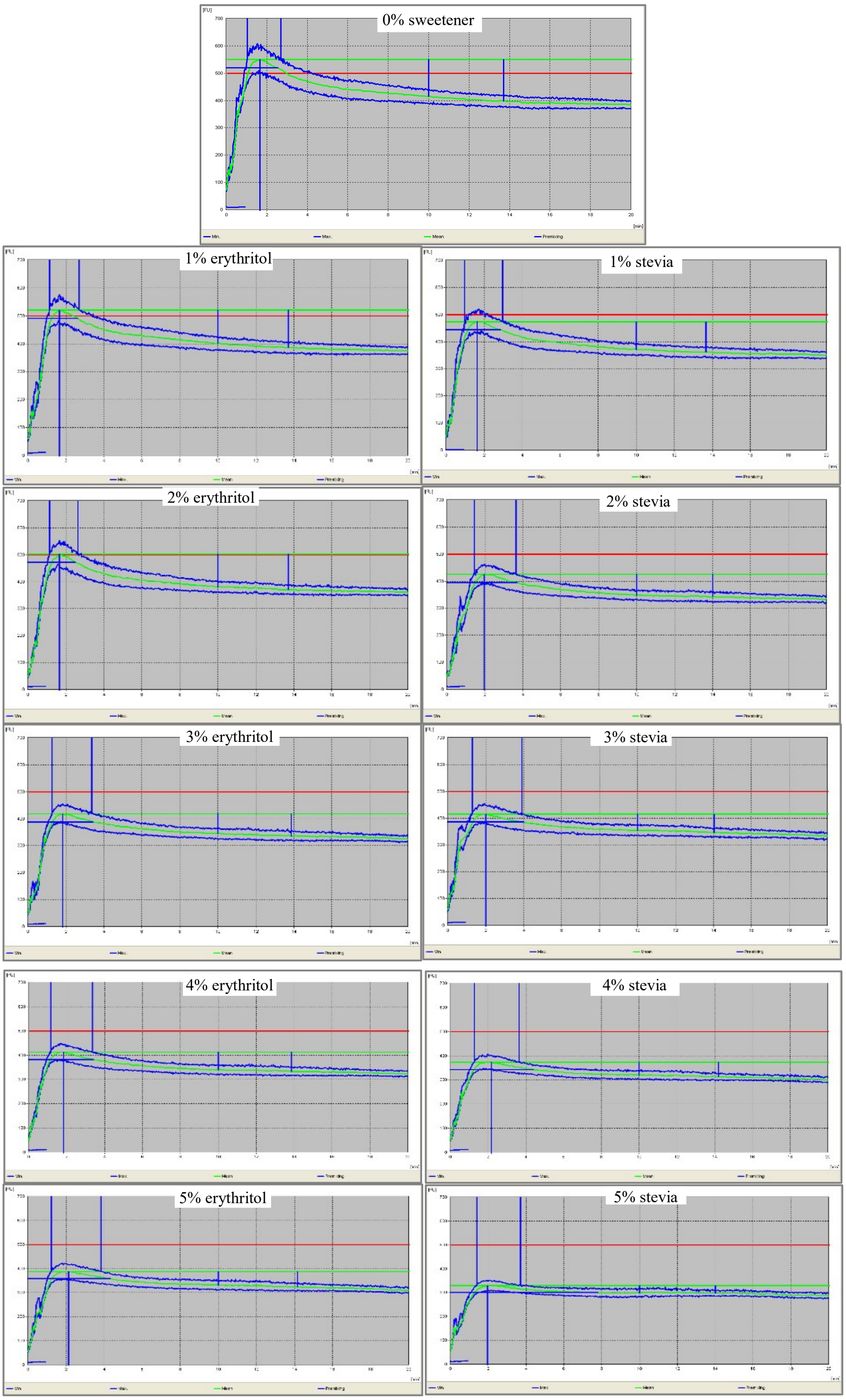

Figure 3. *Farinograph curves obtained from experimental determinations*

The dough consistency (BU) value is correlated with the amount of added water. At the control sample with 0 % added sweetener, the consistency had a maximum value of 550 BU, with the mention that the amount of added water was below the hydration capacity of the flour (see Figure 3 and Table 1). The decrease of dough consistency with the addition of erythritol was in a smaller extent than in the case of stevia addition. As can be seen in the Figure 2 the maximum curve is more pronounced in samples with erythritol with lower decreases than in samples containing stevia. At the maximum of 5 % stevia addition, the dough has a lower consistency (330 BU) than in the sample with 5 % erythritol addition (388 BU). The closest consistency values were seen in the addition of 3 % of stevia and erythritol: 416 BU and 418 BU, respectively.

The dough development time was of 1.7 minutes for the control sample and it has a slight tendency to increase with increasing sweetener percentage, ranging in very tight limits up to maximum of 2.2 minutes for the addition of 5 % stevia and erythritol. So, it can be said that it does not takes more time for gluten to develop in the presence of the two types of sweeteners than without them.

Dough stability increase from 1.7 minutes to 2.6 minutes for both sweeteners added to 5 %. A slight variation is observed in the decrease of stability values to the samples with the addition of 1 and 2 % erythritol (1.6 and 1.5 minutes). The addition of erythritol, increases dough stability at 2.1, 2.2 and 2.6 minutes for the samples with 3 %, 4 % and 5 % addition.

The degree of softening decreased as sweeteners level increased. Samples containing stevia has lower values (from 103 to 32 BU) than the sample containing erythritol (from 121 to 57 BU). Similar results were noticed in paper [11] where degree of softening decreased when a percentage of up 5 % of honey powder was added into dough, but it increased when added honey powder was more than 5 %. So, it is possible that a greater amount of sweetener in dough may weaken its structure, which would causes sticking of dough during kneading and shortening the fermentation time.

The Farinograph Quality Number had a value of 25 for the control sample. This value increased to 78, as the stevia level increased, and to 43 as the erythritol increased. We could say that the flour strength increased with the sweetener level and even more, in the samples where stevia was added the values were higher respect to the previous ones.

CONCLUSIONS

The obtained data may indicate that the addition of sugar substitute in wheat flour affects the rheological properties of dough.

Sugar substitutes influenced the various rheological characteristics of wheat dough depending on the level and type. From the above mentioned, it was seen that the examined sweeteners, stevia and erythritol, had different impact on the dough rheology.

The addition of both sweeteners, stevia and erythritol, reduces the consistency of the dough and the water absorption. Also, the dough development time and the dough stability increase slightly with the increase of stevia and erythritol level, while the farinograph quality number increased significantly especially in the case of erythritol samples.

Knowing the functions and responses of sugar substitutes in dough it is very important to establish when reducing or removing it from the baking products.

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