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APPLICATION OF MICRO Z-ARM DOUGH MIXER IN WHEAT RESEARCH – EFFECT OF PROTEIN ADDITION ON MIXING PROPERTIES OF WHEAT DOUGH

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Abstract

A Micro Z-arm mixer has been developed which needs only four grams of flour per test. The new instrument is suitable for screening new wheat cultivars in the early phase of selection on the basis of dough mixing properties. The micro-scale instrument can also be viewed as a valuable research tool for investigation of the structure/function relationships in flour and the effects of different ingredients and additives on rheological parameters. The effects of protein addition on mixing properties of wheat dough were studied. Alkali-soluble isolates and Osborne protein fractions extracted from wheat, corn-, rice germs and amaranth seeds were used as protein additives. Dough development time, maximum resistance of dough and resistance breakdown was calculated from recorded mixing curves. Results showed that the micro-scale equipment is sensitive enough for detection of the effect of less than 40 mg of protein addition on mixing parameters. The effects of additions depend on the type of proteins added to the wheat flour and the parameters calculated from the mixing curves.

Keywords: wheat, dough mixer, wheat research, wheat proteins.

1. Introduction

The application of small-scale dough testing equipment has many advantages in different research fields, where limited amount of test material is available. Until recently, only the 2g-Mixograph™, a small-scale dough mixer, based on the conventional pin-mixer design was available. The 2g-Mixograph™ has been successfully applied in early selection of wheat varieties and for the determination of mixing properties at the early stages of wheat breeding [1], [2]. The functionality of gluten proteins was also studied with 2g-Mixograph™ by the addition of isolated gluten proteins and their fractions [3], [4], [5], [6]. The micro pin mixer was applied for determination of effect of addition of non-wheat protein isolates as additives into the wheat flour [6], [7]. Doughs made in 2g-Mixograph™ have been used for micro-extension and micro baking tests [8], [9].

One of the most important roles of the 2g-Mixograph™, is to produce dough in a reproducible well documented way for further dough testing, end product quality evaluation and fundamental rheology studies. However, the pin-mixers have not been accepted in applications where determination of water absorption is required. In international standards, Z-arm dough mixers (Farinograph™ or Valorigraf™) are applied for determination of both mixing and water absorption characteristics of wheat flour.

Recently, a prototype of Micro Z-arm Mixer was developed for measuring not more than 4 grams of flour. The Micro Z-arm Mixer mimics the operation of conventional wheat dough testing instruments, such as the Valorigraf™ and Farinograph™. The new instrument consists of a temperature controlled mixing bowl and a speed-controlled, servo-driven DC motor, it has fully automated water addition and computer-controlled operation, data collection and analysis. The results obtained with the new mixer are highly correlated with those obtained with the conventional equipment [10], [11]. In the research work, reported here, the effects of protein addition on dough mixing properties have been studied.

2. Materials and Methods

Materials

The following raw materials were used for protein isolation and fractionation: commercially available food-grade wheat germ (WG); maize germ (MG) from wet chemical process of invert sugar production (Szabadegyháza, Hungary); rice germ (RG) separated in laboratory scale from by-products of rice-whitening process (Szarvas, Hungary) and mixed seeds of two types of amaranth (AM) grown in Hungary (Amaranthus hybridus and Amaranthus cruentus). Australian type of wheat, Rosella was used as control wheat flour with 2^*, $7+8$, $2+12$ HMW allels.

Methods

Protein isolates (WGI, MGI, RGI and AMI) were extracted by one-step alkaline extraction [12]. Protein fractions – albumins (ALB), globulins (GLB) and glutenin-type alkali soluble residue proteins (GLUT) were produced according to the modified Osborne fractionation [7]. The protein content of protein isolates was determined by the automatic Kjeldahl procedure (Kjeltec 1030 Auto Analyser, Tecator AB Sweden).

The water absorption of the control flour was determined with Farinograph™ equipped with 50 g-bowl, according to the ISO standard method (ISO 5530-1). The same water absorption value was used in all experiments.

The mixing properties were determined with the prototype of Micro Z-arm Mixer using 4 g of test flour per mix (*Fig. 1*). Constant angular velocity (shaft speeds of 96 and 64 rpm) was used during all mixes. Each mixing was carried out for 15 minutes in parallel measurements. Before adding water and/or proteins to the flour, the baseline was automatically recorded (30 sec) by mixing only the solid components. The rates of protein addition were 10 and 20% calculated from the protein content of Rosella flour. The water addition was carried out in one step using the automatic water pump. The following mixing parameters were determined (*Fig. 2*): Mixing Time (MT), Peak Resistance at maximum (PR) and resistance Breakdown (BD) [10], [11].

To verify the statistical significance of the measured parameter means, SD values were calculated from parallel measurements, $p = 0.05$ were considered as significant. STATISTICA version 5.5 software (Statsoft Inc., USA) was used for calculations.

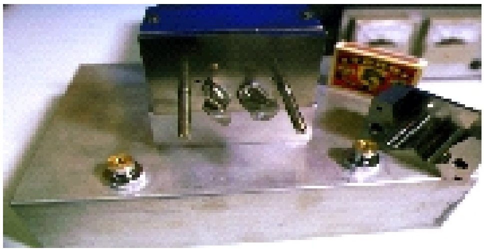


Fig. 1. The prototype of Micro Z-arm Mixer

3. Results and Discussion

The protein contents of raw materials, protein isolates and fractions are summarized in *Table 1*. The protein content of fractions is between 40–80% (w/w) indicating that these fractions – and mainly albumins – contain not only proteins but also carbohydrates. This is valid primarily for the albumin fraction.

Differences in dough properties are largely determined by superimposition of the effects of protein content, protein quality, glutenin-to-gliadin ratio and the size distribution of the polymeric glutenin. The changes of water absorption and mixing properties of wheat flour with the addition of wheat protein fractions were

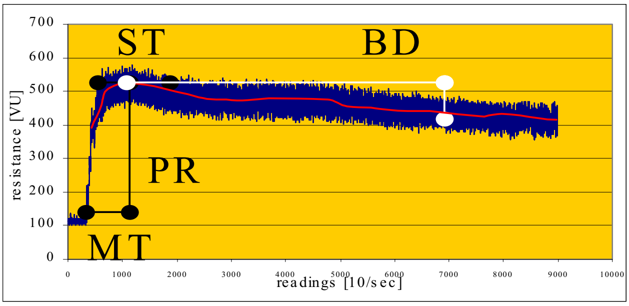
Table 1. Protein content of isolates and fractions extracted from cereal germs and amaranth (WG: wheat germ, MG: maize germ, RG: rice germ, AM: Amaranth, I: alkaline protein isolate, ALB: albumin, GLB: globulin, GLUT: glutenin-type protein fractions)

Sample name	Protein content [%, w/w)]	Sample name	Protein content [%, w/w)]
Wheat germ (defatted)	29.66	Rice germ (defatted)	21.65
WG–I	89.58	RG–I	81.10
WG–ALB	40.2	RG–ALB[1]	47.9
WG–GLB	92.8	RG–GLB	89.1
WG–GLUT	72.9	RG–GLUT[1]	53.66
Maize germ (defatted)	23.16	Amaranth (defatted)	15.32
MG–I	87.84	AM–I	79.80
MG–ALB	42.44	AM–ALB	39.61
MG–GLB[1]	69.00	AM–GLOB	73.68
MG–GLUT	69.27	AM–GLUT	80.1

[1]not used in these experiments

studied previously by micro-scale mixers [6], [13]. In our present study, the effect of non-wheat protein fractions on mixing properties of wheat flour was investigated.

It was found, that changes in the flour protein content by addition of non-wheat flour protein isolates and fractions were reflected in the mixing parameters obtained with the Micro Z-arm mixer. The mixing time decreased if protein content was increased by addition of defatted wheat, maize and rice germ flour and protein fractions – except of albumins. However, the addition of amaranth flour and proteins increased the dough development time significantly (*Fig*3). In case of maximum peak resistance the effect of protein addition was opposite: in almost all cases the peak resistance was increased except of cases of albumin addition, where the peak resistance was decreased (*Fig.* 4). According to the standard methodology of Farinograph- or Valorigraf-type measurements, the increase of maximum peak resistance means the increase of water absorption. In other words, the addition of investigated plant proteins increased the water absorption of wheat flour, except of cases of albumin addition. There were no similar tendentious effects in case of resistance breakdown. Addition of WG flour, WG-I, WG-GLB, MG flour and RG flour did not change significantly the stability of control wheat flour. (*Fig.*5). WG-GLUT, MG-I, MG-GLUT and RG-I increased this calculated parameter meaning that the dough stability was weaker in these experiments. The results show unambiguously, that the addition of all protein samples originated from amaranth improved the stability of control dough. The same effect was observable when albumin fractions were added.



MT **M**ixing **T**ime (sec)
PR **M**aximum **R**esistance (VU or A.U.)
ST **ST**ability (sec)
BD Resistance **B**reak**D**own (VU*s)

Fig. 2. A typical mixing curve registered in Micro Z-arm mixer and the parameters calculated form the curve

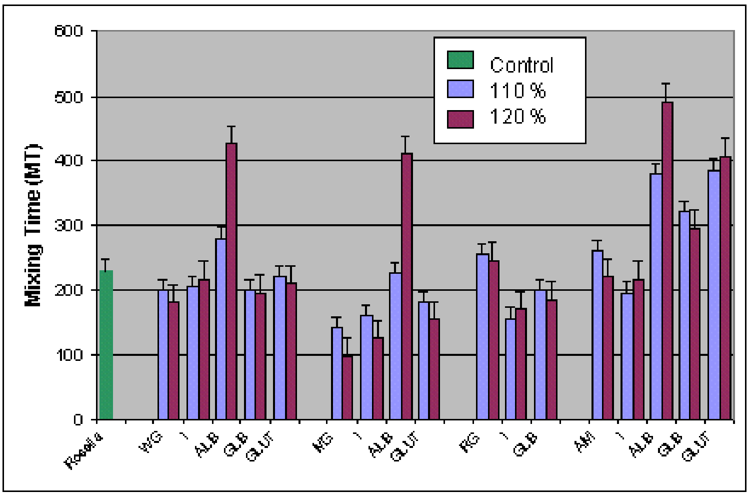


Fig. 3. Effect of protein addition on Mixing Time (MT) of wheat dough. The additives were supplemented with 110% and 120% on protein base. (WG: wheat germ, MG: maize germ, RG: rice germ, AM: Amaranth, I: alkaline protein isolate, ALB: albumin, GLB: globulin, GLUT: glutenin-type protein fractions)

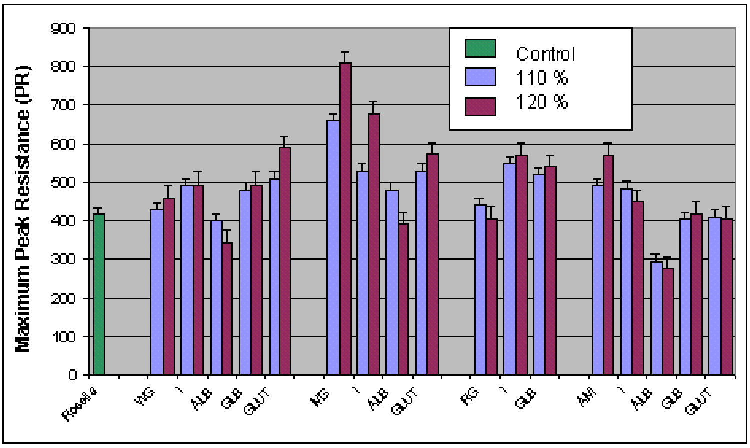


Fig. 4. Effect of protein addition on maximum Peak Resistance (PR) of wheat dough. The additives were supplemented with 110% and 120% on protein base. (WG: wheat germ, MG: maize germ, RG: rice germ, AM: Amaranth, I: alkaline protein isolate, ALB: albumin, GLB: globulin, GLUT: glutenin-type protein fractions)

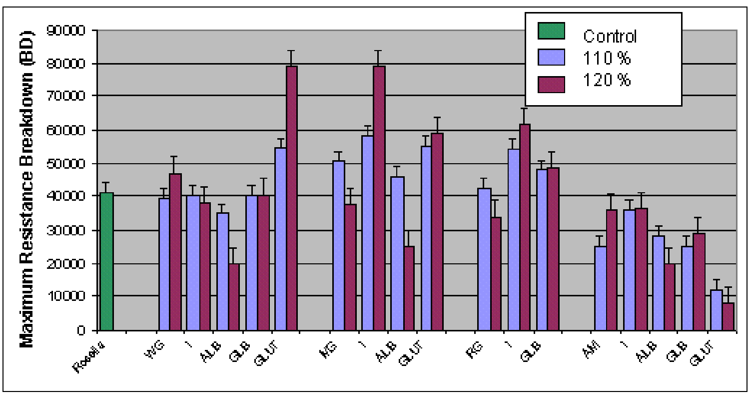


Fig. 5. Effect of protein addition on resistance BreakDown (BD) of wheat dough. The additives were supplemented with 110% and 120% on protein base. (WG: wheat germ, MG: maize germ, RG: rice germ, AM: Amaranth, I: alkaline protein isolate, ALB: albumin, GLB: globulin, GLUT: glutenin-type protein fractions)

From viewpoint of bread making quality and technology the decreased mixing time and increased stability mean better quality. In our experiments the addition of cereal germ proteins has advantageous effect on mixing time, but the changes of dough stability was inconsistent. The additives originated from amaranth showed different changes in dough properties: in almost every case, the mixing time was increased while resistance breakdown was decreased by the addition. The effects of all albumin fractions were very similar and were different from the effects of other additives. The carbohydrate content of albumins could play a major role in these effects.

These findings are analogous, but are not the same to those obtained from studies carried out on pin mixers, on 2g-Mixograph [7]. The changes of MT and BD by the addition of the same proteins were very similar. However, the effects of protein supplement on PR were different. This alteration could be originated from the different mixing actions. Due to this fact, the shapes of the registered curves obtained by pin mixer and Z-arm mixer are different. In case of pin mixer, the determination of maximum peak height is not too ambiguous and the standard method does not contain the determination of water absorption. Our results gave another proof, that the mixing procedure influences the dough properties and/or the mixing curves registered with different mixers contain different information for dough properties.

4. Conclusions

The micro Z-arm mixer provides a new method to determine the effects of protein addition on mixing properties of wheat flours. Due to the small amounts of additives needed for measurements, Micro Z-arm mixer could be a valuable research tool for the investigation of structure/function relationships in flour. The cereal germs, amaranth and/or their protein fractions could be valuable, natural and functional additives for improving the dough properties.

However, it should be noted that in our experiments only one wheat variety was used as control material. Due to the fact that the mixing properties strongly depend on the protein structure of gluten, the effects of protein supplementation of different wheat species could be different. On the other hand, to establish cause–effect relationships between chemical composition and functional parameters, experiments are needed where only one parameter is altered [13]. In our research the protein quality, structure and content were changed in the same time, resulting a complex effect on dough mixing parameters. These difficulties point out the directions of further experiments for better understanding the effects of additives used on dough quality.

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