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# Muffins with resistant starch: Baking performance in relation to the rheological properties of the batter

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**Abstract**

The effect on baked muffins of progressively replacing wheat flour with resistant starch (RS) was studied. Muffin volume and height and the number and area of gas cells decreased significantly when the RS level reached about 15% (by weight of total formulation) or higher. Rheological properties of the raw batters were studied: the mechanical spectra of batters at 25 °C, the evolution of the dynamic moduli ($G'$ and $G''$) with rising temperatures (from 25 to 85 °C) and the mechanical spectra at 85 °C were obtained from oscillatory rheological tests. The decrease in the viscosity and in the elastic properties of the muffin batter as the flour was increasingly replaced by RS was related to the baking performance of the final baked products.



*Keywords:* Resistant starch; Batters; Muffins; Rheology; Gas cell

## 1. Introduction

Resistant starch (RS) has been defined as the sum of starch and starch degradation products not absorbed in the small intestine of healthy individuals (Asp and Björck, 1992). According to the latest definition of dietary fibre (De Vries, 2003), RS is considered dietary fibre and is determined as such by the official method for the regulatory determination of Total Dietary Fibre, AOAC 991.43 (Haralumpu, 2000). Some of the benefits of RS resemble those of traditional fibre and others are unique to RS. One of the interesting characteristics of RS is its pattern of fermentation in the colon, principally the profile of short chain fatty acids.

The intake of fibre and fibre-containing foods is below the recommended levels in all Western countries. For this reason, efforts have been made to develop fibre-enriched foods. Ideally, the foods to fortify are those that taste good and are often eaten. Several dietary fibres have been employed to produce high fibre content muffins and cakes. Shafer and Zabik (1978) compared the effect of replacing 30% of the flour with different dietary fibre sources (wheat, corn, soy, and oat brans) on raw batter and final cake quality parameters measured both instrumentally and sensorially. Cakes with wheat bran had little effect on cake quality, cakes made from corn bran had the largest volume of any cake, and cakes with soy and oat bran were scored with a poor flavour. The suitability of apple fibre (4%) in comparison to wheat and oat brans was studied by Chen et al. (1988). The addition of this fibre produces an increase in muffin density, low density is associated with good muffin quality. Isolated fibres from wheat, pineapple and field bean seed hulls were included (5% w/w) in a sponge cake preparation without altering the volume and sensory properties of the final product (Sreenath et al., 1996). Grigelmo-Miguel et al. (2001) studied the feasibility of peach dietary fibre to replace oil in a standard muffin recipe; acceptability studies revealed no differences between the control and muffins with 4% of peach fibre. In comparison to traditional fibre, RS possesses the advantage of its white colour and low water retention properties (Yue and Waring, 1998), so it should cause less alteration to the sensory properties of the final baked product as well as to

*Abbreviations:* RS, resistant starch; SAOS, small amplitude oscillatory shear; SG, specific gravity

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its manufacturing process (Wepner et al., 1999). When RS was used to replace 12.5% of the shortening, yellow layer cake quality was improved (Lin et al., 1994). Not many information about incorporating RS into muffins or cake systems appears to have been published.

A muffin batter is a complex mixture of interacting ingredients; basically, a standard muffin formula is composed of a high level of sugar and variable levels of fat, flour, eggs, and baking powder. Other commonly used ingredients are emulsifiers, preservatives, and milk powder. Muffins are characterized by a typical porous structure and high volume. To obtain such a structure, a stable batter lodging many tiny air bubbles is required. The bubbles are produced during the mixing process. After mixing, the bubbles will act as nuclei and grow in size when the carbon dioxide gas generated by the baking powder leavens the product during baking. Eggs, egg white and, to a lesser extent, milk proteins are important foam stabilizers, slowing down the coalescence of air bubbles. Shortening and oil are used to give a softer structure and avoid a dry mouth feel (Lallemand Baking update, 2000). Gelatinization of the starch from the flour and protein denaturising sets the structure during baking. Sucrose increases the starch gelatinization and protein denaturising temperatures, giving the cake time to rise (Hoseney, 1994).

The viscous behaviour of the batter system is a controlling factor in the final cake volume, due to its effects on bubble incorporation and movement (Bath et al., 1992; Handleman et al., 1961; Kim et al., 2001). The rate at which bubbles rise due to buoyancy is inversely proportional to viscosity. Thus, rapidly rising bubbles in a low-viscosity cake batter may result in cake volume loss. Higher cake batter viscosities help to incorporate more air bubbles into the batter and keep them from escaping from the mass, giving the cake system more stability. Coalescence is the most important process by which cells disappear in porous bakery products.

Studying viscoelastic behaviour through small amplitude oscillatory shear (SAOS) gives very valuable information about the structural properties of a system. Information about the oscillatory rheological characteristics would help to understand the structure of the raw batter and its changes during heating.

The aims of this investigation were to study the effect of replacing wheat flour with different amounts of RS on the baking performance of a muffin batter formulation and to relate this effect to the linear viscoelastic properties of the raw batter before, during and after heating to a certain temperature.

## 2. Experimental

### 2.1. Batter and muffin preparation

Five formulations were prepared using the same quantity of all the ingredients except the flour and RS, which were 26/0%, 21/5%, 16/10%, 11/15% and 6/20%, respectively. The ingredients used in the preparation of the muffin batters were wheat flour (Harinera Vilafranquina, S.A., Teruel, Spain) (composition data provided by the supplier: 14.5% moisture, 10.1% protein); RS (HI-maize 1043, National Starch Food Innovation, Manchester, UK) (composition data provided by the supplier: 12% moisture, 63.9% dietary fibre); 26% sugar (Azucarera Ebro, Madrid, Spain); 14% liquid pasteurized egg white and 7% liquid pasteurized yolk (Ovocity, Llombay, Spain); 13% full-fat milk (Puleva Food, Granada, Spain); 12% refined sunflower oil (local supermarket); 1.03% bicarbonate of soda (A. Martínez, Cheste, Spain); 0.79% citric acid (A. Martínez, Cheste, Spain), and 0.18% grated natural lemon peel. The egg white was whipped in a mixer (Kenwood Major Classic, UK) for 2 min at speed 7 (maximum). Sugar was then added and mixed in for 30 s at speed 7. Egg yolk, citric acid and milk (6.5%) were added and mixed in at speed 3 for 1 min. Wheat flour, RS, bicarbonate of soda and grated lemon peel were added and mixed in at speed 3 for 1 min. Oil and milk were added and mixed in at speed 4 for 3 min. The batter was placed in an automatic dosing unit (positive displacement pumps, output shaft speed = 109 rpm, output shaft torque = 7.6 N m) (Edhard Corporation, Hackettstown, USA) and each paper muffin cup (50-mm diameter) was filled with 40.5 g of batter. The muffins were baked in a conventional oven for 6 min at 225 °C and a further 6 min at 175 °C. The oven and oven trays were always the same, the trays were placed at the same level in the oven and the number of muffins baked was always the same. The muffins from each formulation were prepared twice, on different days, with 24 muffins in each batch.

### 2.2. Specific gravity (SG) of the batter

The SG of the raw batter was measured with a small cup of known volume. It was determined gravimetrically by dividing the weight of this known volume of batter by the weight of an equal volume of water. The measurements were made in triplicate.

### 2.3. Rheological properties of the batter

During the rheological determinations, special attention was paid to maintaining samples with the same thermo-mechanical history before testing. Accordingly, the batters were all kept at 25 °C for 1 h after batter preparation before the rheological test. The samples were then allowed to rest in the measurement cell for a 1400 s equilibration time. To protect against dehydration during long measurement times, vaseline oil (Panreac Química S.A.) was applied to the exposed surfaces of the samples and they were covered with a glass cup.

#### 2.3.1. Flow properties

The flow properties of the muffin batters were studied using a Physica Rheolab MC 120 rheometer (Paar Physica,