In-depth Understanding of Ingredient Functionality in Cake as a Basis for Clean Label Products: Bleached Flour Replacement

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Cakes baked for celebrations often consist of alternating layers of cake and cream that are covered and decorated with icing and/or cream. The cake layers must have a very fine and homogenous structure, as well as a firm, resilient, and moist texture to provide the mouthfeel typically associated with these cakes and to provide stability for the superimposed layers. To create a layer cake, a high-ratio cake formula is used. In a high-ratio cake formulation the amount of sugar, liquid, or both exceeds the amount of flour used. (If the amounts of sugar and liquid are lower than that of flour, the resulting product is commonly referred to as a low-ratio cake.)

The production of a high-ratio cake with acceptable volume, fine and homogenous crumb structure, and firm, resilient (i.e., no structural collapse during or after baking), and moist crumb typically requires use of chlorinated or bleached flour (i.e., flour treated with chlorine gas [Cl_2]) and a suitable emulsifier in the formula. The use of chlorinated cake flour allows lower proportions of flour and higher proportions of sugar and/or liquid to be used in the cake formulation.

Cl_2 is commercially applied at a rate of 300 to 1,500 mg/kg of flour (6). It reacts with the water contained in the flour (flour typically has a moisture content of about 14.0%) as follows:

$$Cl_2 + 3H_2O \rightarrow 2H_3O^+ + OCl^- + Cl^-$$

The hypochlorite ion (OCl^-) that is formed is a strong oxidizing agent, acting on flour carotenoid pigments that are part of the lipid fraction and rapidly decreasing their levels. This oxidation activity bleaches the flour (8). The hydrogen ions that are formed lower the flour pH (3), and the decrease in pH is monitored to obtain the desired level of chlorination (7).

During the 1980s and 1990s the use of Cl_2 to treat flour was debated because of safety issues associated with its use in the flour milling industry, as well as with the presence of Cl_2 in foods. As a result of these concerns, the use of chlorinated wheat flour in cake and bakery applications was banned by the European Food Safety Authority (EFSA) in 1998 and since then has been banned in China, Indonesia, Korea, Japan, Brazil, and Argentina.

Today consumers are seeking cakes made with more natural ingredients and fewer additives—ingredients that are more easily understood and not associated with health risks. Recent proprietary research on consumer insights shows 80% of consumers are unfamiliar with surfactants and their role in baking, leading to consumer misunderstanding of their functionality. The research also showed that consumers associate chlorinated flour with potential health and environmental effects, such as inflammation, toxicity, and carcinogenic properties. To meet consumer demands retailers are increasingly taking the initiative to eliminate chlorinated flour and some emulsifiers from their accepted ingredients lists.

In order to replace chlorinated flour with an alternative that will perform equally well, many researchers have attempted to determine the effects of Cl_2 treatment on individual flour components. No consensus has been reached, however, concerning which modification is most important for the observed changes in flour functionality. It has been shown that OCl^- reacts with starch (1), gluten (2), lipids (4), and arabinoxylan (5). The exact portion reacting with each flour component has been difficult to determine, and it is still not clear how the altered starch, gluten, and lipid properties in chlorinated flour result in improved high-ratio cake quality. As a consequence, further research on the changes in flour induced by chlorination is needed.

Removing both chlorinated flour and emulsifiers (specifically polyglycerol ester [PGE] and propylene glycol monoester [PGME]) from the formulation of high-ratio cakes while maintaining specific high-ratio cake characteristics (i.e., a very fine, white crumb structure and specific texture properties) is not a straightforward process. In a joint research effort KU Leuven (Laboratory of Food Chemistry and Biochemistry) and Puratos have extensively studied the functionality of chlorinated flour in high-ratio cakes. A brief summary of the outcome is outlined below.

Removing and Replacing Ingredients—The Science Behind It All

The research showed that Cl_2 modifies the structure of the main soft wheat flour components (protein, starch and lipids), altering their functionality in high-ratio cakes. Cl_2 treatment increased the surface hydrophobicity of the starch granules and reduced the gluten network-forming capacity and apparent free fatty acids content of the flour—the latter presumably by forming chlorinated derivatives. The treatment also increased the water-holding capacity of the flour. This agreed with results reported in the literature. In addition, the altered component functionalities resulted in improved gas cell stabilization and earlier batter viscosity readings, matrix solidification, and crumb setting during baking. The latter was attributed to improved starch swelling and amylose leaching caused by changes in starch, protein, and lipid properties, as well as to changes in the protein polymerization mechanism that resulted in increased protein network strength. After heating, starch and protein networks in gels prepared from chlorinated flour were more structured than in gels prepared from untreated flour when observed using proton nuclear magnetic resonance.

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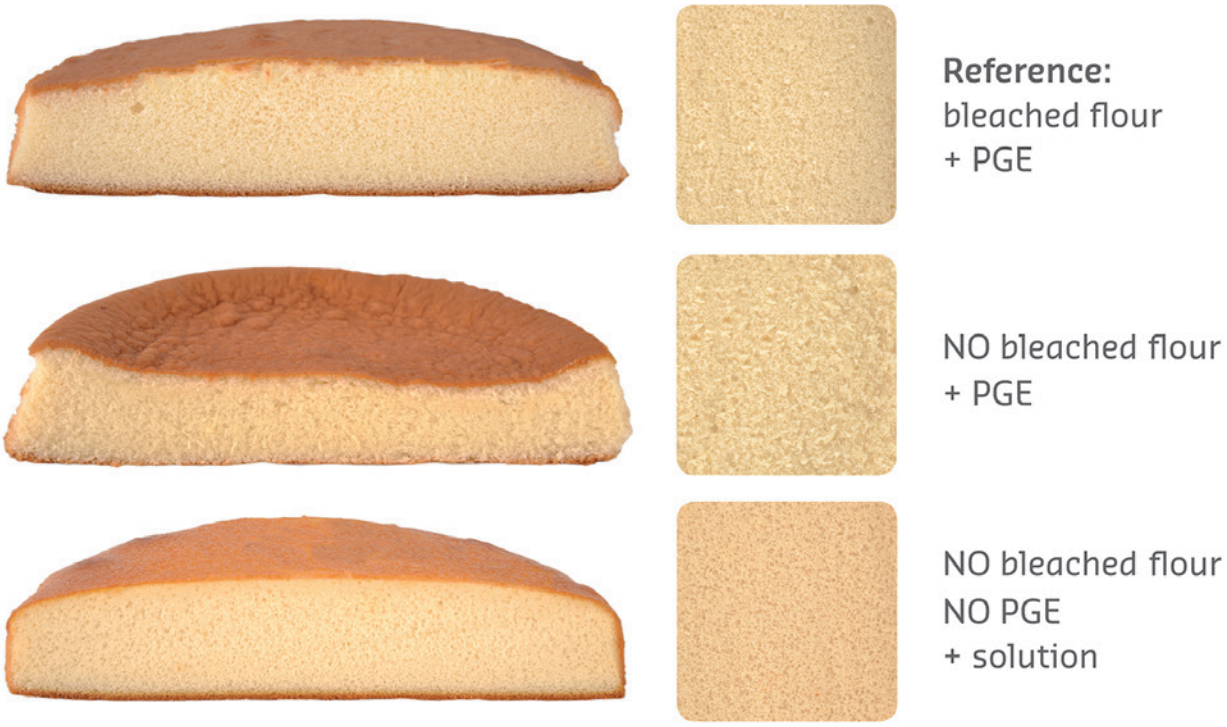

Fig. 1. White layer cake prepared from three high-ratio cake formulas. Top: cake made with bleached flour and polyglycerol ester (PGE); middle: cake made with PGE and no bleached flour; bottom: cake made with no bleached flour and no PGE and reformulated with solution.

These findings helped Puratos develop a solution for replacing chlorinated flour, which consists of a combination of ingredients that synergistically provide fast hydration, viscosity buildup, and stabilization of oil droplets and gas cells during the batter stage and baking. This solution can be applied in a clean label, high-ratio cake formula that maintains the characteristic appearance and eating properties of standard layer cakes available in the U.S. market without using chlorinated flour, PGME, or PGE (Fig. 1). This solution received a 2018 innovation award from the American Society of Baking (ASB), a professional organization dedicated to advancing baking and baking science technology.

References

1. Baldwin, P. M., Melia, C. D., and Davies, M. C. The surface chemistry of starch granules studied by time-of-flight secondary ion mass spectrometry. J. Cereal Sci. 26:329, 1997.
2. Duviau, M. P., Yamamoto, H., Ng, P. K. W., and Kobrehel, K. Modifications of wheat proteins due to flour chlorination. Cereal Chem. 73:490, 1996.
3. Gough, B. M., Whitehouse, M. E., Greenwood, C. T., and Miller, B. S. Role and function of chlorine in preparation of high-ratio cake flour. CRC Crit. Rev. Food Sci. Nutr. 10:91, 1978.
4. Heikes, D. L. Mass-spectral identification and gas-chromatographic determination of chlorinated bleaching adducts in flour-containing food items. J. Agric. Food Chem. 40:489, 1992.
5. Kweon, M., Slade, L., Levine, H., and Souza, E. Application of RVA and time-lapse photography to explore effects of extent of chlorination, milling extraction rate, and particle-size reduction of flour on cake-baking functionality. Cereal Chem. 87:409, 2010.
6. Pyler, E. J. *Baking Science and Technology*, vol 2. 3rd ed. Sosland Publishing Company, Kansas City, MO, 1988.
7. Sollars, W. F. Cake and cookie flour fractions affected by chlorine bleaching. Cereal Chem. 35:100, 1958.
8. Tsen, C. C., Kulp, K., and Daly, C. J. Effects of chlorine on flour proteins, dough properties, and cake quality. Cereal Chem. 48:247, 1971.

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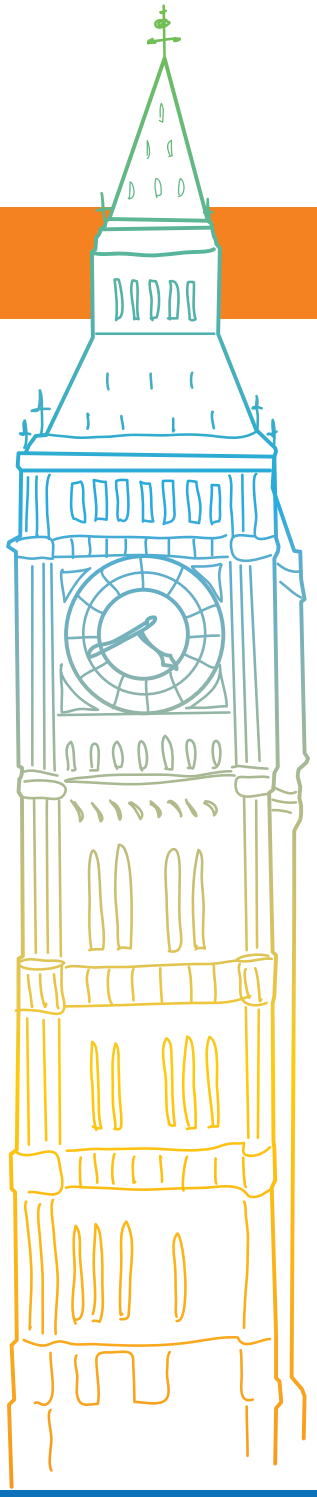

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