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Changing flour functionality through physical treatments for the production of gluten-free baking goods

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ABSTRACT

It is common to fall back on the use of gluten-free flour from cereal, or from other grains, such as legumes or pseudocereals for gluten-free products development. Traditionally, the industry has approached the use of native flours, without modification, whose properties depend on grain characteristics and composition as well as the milling system used. Nevertheless, flours obtained from traditional methods can be subjected to different physical treatments, which range from a simple sieving to complex hydrothermal treatments which can modify flour functionality and their adequacy to the different gluten-free elaborations. In this review, the different physical modifications can be submitted to flours and the way they change flour functionality have been analysed. Thereby, the influence of flour particle size, fine grinding and air classification processes, and the different modalities of dry and wet thermal treatments on flour properties have been discussed. The review concludes by explaining the utility and the potential uses of these physical treatments on gluten-free products.

1. Introduction

Many bakery products are manufactured with wheat flour in occidental countries. In some cases, during processing, gluten network is formed when wheat proteins are hydrated and subjected to mechanical work, playing a key part in the development and final quality of these products. Breads and other fermented doughs are clear examples. Nevertheless, in other cases, due to either the lack of hydration or mechanical work, gluten network is not created and its role is not indispensable for the development of products such as cakes or cookies. In order to make gluten-free bakery products, a common practice is to use starch-based materials. Corn or tuber starches and corn and rice flours are the most used (O'Shea et al., 2014), although recently an increasing interest in other gluten-free flours such as teff, sorghum, millet, buckwheat, quinoa or amaranth has been observed. Added to that, wheat starch and oat flour, as long as they are produced under conditions which guarantee the absence of gluten, have also been taken into account. When the development of a gluten network plays an important role, the use of a gluten replacer is common, for what is typical to incorporate hydrocolloids.

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2. Particle size classification

In general, research on the development of gluten-free products does not go into depth on the characteristics of flours or starches for their adequacy to each of the bakery products. However, it is demonstrated that these characteristics have a strong influence on the quality of the final product. Thereby, apart from some characteristics which can be influenced by the genetic or cropping conditions, such as protein content or amylose/amylopectin ratio of starch, other features can be modified as a function of the production methods of flour and starch, such as damaged starch or particle size. These features will be determinant in the homogeneity and the final quality of the obtained products. In this way, Kadan et al. (2008) and Araki et al. (2009) observed that the milling system affected the damaged starch and particle size of rice flour and therefore the volume of breads was also affected. These authors found a high negative correlation between damaged starch and bread specific volume. Nevertheless, it is worth noting that these authors added wheat gluten to the recipe, thus these results would not be completely extrapolated to gluten-free breads. In fact, de la Hera et al. (2013a) reported that as the particle size of rice flour was reduced by sieving, the specific volume of gluten-free breads, made with 80% of water flour basis (f.b), decreased. This effect was attributed to the behaviour of doughs during fermentation, since doughs made with fine flours were scarcely able to retain gas produced in this step, which in turn could be due to the structural differences observed among the different doughs. Nonetheless, in the case of flours made with higher hydration (110% f.b), these effects became less clear and only a noticeable reduction of the gas retention and bread volume in the case of the finest flour (<80 μm) was reported. In general, the finest flour gave rise to doughs with lower gas retention capacity, but this effect only was observed from a certain fermentation time. These results seem to endorse the theory of a low volume of breads made with flours with higher damaged starch. However, differences in the damaged starch content among the flours classified by sieving were small and, converse to what was expected, the finest fractions were those which displayed a lower content of damaged starch (de la Hera et al., 2013b). In this study, the finest particles were obtained through sieving a set of particles of different sizes instead forcing to reduce the size of all particles during milling. Therefore, the scarce differences in the damaged starch content among flours can be due to the fact that the finest fractions come mainly from the softest parts of the grain which are broken into smaller pieces naturally, without forcing the milling. Therefore, the damaged starch itself cannot explain these differences on bread volume. Neither can these differences be attributed to the different protein content nor to the amylose/amylopectin ratio, since no correlations were appreciated. Nevertheless, the differences observed could be attributed to the higher water absorption capacity of the finest flour due to its greater surface to volume ratio. In fact, the effect observed would coincide with the lower volumes obtained using flours with higher damaged starch, which possesses higher water absorption capacity than native starch. This occurrence would also allow explaining the fact that the differences in bread volume diminish in excess of water. By studying semi-dry milled rice flours obtained by air classification, Park et al. (2014) also observed that the finest fractions gave rise to breads with lower volume, even though a low damaged starch content (<5%) was presented. Meanwhile, in bread-making using corn flour, flour characteristics also had a strong influence on bread quality. Breads with the highest volume were those made with some flours of the highest particle size and with lower water absorption capacity. However, one of the finest flours with similar water absorption capacity gave rise to breads with much lower volume. Therefore, the water absorption capacity of flours cannot fully explain the effect of the particle size on bread volume. On the other hand, differences in bread volume could be attributed to the different hardness of flour particles and their morphology. In general, as it was observed with rice flour, finer flours gave rise to breads with lower specific volume (de la Hera et al., 2013c). Added to that, in whole grain oat flour bread-making, oat flours with coarse particle size, limited starch damage and low protein content resulted in superior oat bread quality (Hüttner et al., 2010). Therefore there is a clear effect of flour particle size on gluten-free bread-making. In general not too much fine flour is preferred, even though this can vary as a function of the milling method, type of grain and bread-making process. In Fig. 1, this effect can be observed clearly. This occurrence can be diminished by increasing the water amount in the recipe. However, deeper studies using other types of gluten-free flours and other milling systems are necessary in order to confirm these observations. From a nutritional perspective, and converse to a functional point of view, the best combination would be using the lowest dough hydration meaning a lower volume and greater bread hardness (de la Hera et al., 2014). Those authors reported that a reduction of the dough hydration could limit the starch gelatinization and hinder the *in vitro* starch digestibility. In addition, the coarsest flours exhibited a lower hydrolysis rate and a greater amount of slow digestible starch (SDS) and resistant starch (RS). Thus, besides the particle size, dough hydration should also be taken into account for modulating the enzymatic hydrolysis of gluten-free starchy foods.

In the case of cake-making, it is known that particle size influences their quality, even in those made with wheat flour, the use of fine flours was preferable (Gaines, 1985; Gómez et al., 2010; Yamamoto et al., 1996; Yamazaki and Donelson, 1972). In the case of gluten-free flours, such as rice or corn ones, the greater hardness of the initial grains make these flours have a higher particle size, which can cause problems in the product quality. In cakes made with rice flour, Bean et al. (1983) claimed that flours derived from long grains gave rise to cakes with lower quality (volume, texture and appearance). Those authors attributed those differences to the different viscosity profiles displayed in a heating–cooling cycle, but they did not analyse the particle size of flours. In fact, the authors mentioned a more grainy texture in cakes obtained from long grain rice varieties, thus it is possible that these are coarser, a characteristic which could have influenced the results. Thereby, de la Hera et al. (2013d) observed that the particle size of rice flours was a determinant factor on cake quality. Moreover, these authors claimed that it was due to the characteristics of the emulsion formed in the stirring step. As the particle size increased, the incorporated air displayed larger and more irregular bubbles, the emulsion was less stable and therefore cake volume was lower. These authors also observed that the effect of the particle size was higher in sponge cakes than in layer cakes, which could be due to the fact that in the former, the air bubbles are much finer, but they are not stabilised by a lipidic phase, more important in layer cakes. Besides, baking powder was not added into the recipe of sponge cakes and the volume increase in the baking step was mainly triggered by the expansion of entrapped gas. The effect of the particle size was confirmed later in cupcake-making by Kim and Shin (2014), who reported that it was preferable to remove the coarsest fractions in order to achieve cupcakes with higher specific volume, lower hardness and better sensory assessment.

In the case of cookie-making with wheat flours, both their particle size and damaged starch content, and therefore the milling system, are key factors which determine the characteristics of the final product (Barak et al., 2014; Moiraghi et al., 2011; Yamamoto et al., 1996). This relationship can be due to the influence of these parameters on water absorption capacity of these flours and therefore dough rheology, as well as to structural effects. Moreover, particle size of legume flours, which supplement wheat flours in cookie-making, affects cookie quality greatly, and in particular the hardness and the spread factor of cookies increase and decrease as particle size is reduced, respectively (Zucco et al., 2011). Even though particle size is not analysed in the vast majority of studies on gluten-free cookies, the higher hardness of the used grains compared to wheat ones, can make them display a higher granulometry as Torbica et al. (2012) observed. In general, there is a lack of studies which relate flour properties, including particle size or damaged starch, and not only their origin, with gluten-free cookie quality. In this way, this parameter should be included in the characterization of the flours used in these type of studies.

According to these studies, a simple classification of gluten-free flours based on their particle size, and the subsequent election of the proper fraction, could improve their suitability for the manufacturing of gluten-free products such as bread, cakes or cookies.

3. Fine grinding and air classification

Once having obtained flour, this can be subjected to different physical treatments with the aim to achieve flours with different functionality and nutritional composition. One of the most interesting physical treatments is micronization (fine grinding) and the subsequent air classification. This treatment includes reducing the