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Original article

Wasted bread flour as a novel ingredient in cake making

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Abstract Bread is one of the most wasted products in both industry and retail. This study analysed the use of bread flour of various particle sizes (1000 μm, 500 μm and 200 μm) in different percentages for sponge formulations (10% and 20%) and layer cakes (10%, 20% and 30%). Viscosity, microstructure and density of batters, as well as specific volume, texture and colour of cakes were evaluated. The inclusion of bread flour change batter microstructure. Viscosity does not affect the sponge batters but it tends to increase in the layers, mostly in the case of finer flours. The specific volume is reduced in sponge cakes while hardness is generally increased, even with the lowest percentages of bread flour. In layers, this reduction in volume is only visible at the highest doses of flours below 500 microns with no changes in hardness.

Keywords Bread flour, food waste, layer cakes, sponge cake.

Introduction

Roughly, one-third of the food produced worldwide is wasted (Stenmarck *et al.*, 2016). In the European Union (EU), this value corresponds to a loss of approximately 143 billion euros per year (Tonini *et al.*, 2018). Such losses imply a high environmental impact that can be reduced by minimising these wastes or through better practices in their handling (Benabda *et al.*, 2018). Nowadays, the EU prioritises the sustainability of food systems and circular economy to reduce the environmental impact. It recommends the reuse of all waste suitable for human consumption to be reintroduced on the food chain (European Union, 2008). Within the bakery industry, bread is the most wasted food (Brancoli *et al.*, 2017). Research has been conducted into the use of wasted bread as an ingredient for food production, especially for its reintroduction in different products, such as sourdoughs (Gélinas *et al.*, 1999), extruded snacks (Luo & Koksel, 2020; Samray *et al.*, 2019) or cookies (Guerra-Oliveira *et al.*, 2021).

Wheat flour components undergo important modifications in the baking process that change their functionality. Thus, the baking process promotes gluten denaturation (Pagani *et al.*, 2020), starch gelatinisation (Martínez *et al.*, 2013) and the inactivation of the enzymes present in the dough (Hug-Iten *et al.*, 2003), among others changes. As a result, flours increase their water absorption capacity and their thickening power when cold, but they reduce their capacity to increase the consistency of doughs when heated, as well as to form strong gels (Fernández-Peláez *et al.*, 2021).

Cake is a popular bakery product with good acceptance among consumers (Jeddou *et al.*, 2017). Starch granules potentially contribute to the stability of the air–water interface of the sponge cake batter; during baking, when starch gelatinises, it helps to set the final structure (Godefroidt *et al.*, 2019). Flour also helps increase viscosity in layer cake batter, which restricts migration and coalescence of both fat particles and gas cells and, thus, contributes to a stable batter emulsion and foam (Wilderjans *et al.*, 2013). Gluten network formation is minimal in this type of baking and it will depend on the type of cake; however, it can also influence the final structure by preventing collapse (Wilderjans *et al.*, 2008). Selection of a suitable flour for cake production usually involves the analysis of its water absorption capacity and particle size, as these factors influence the ability to stabilise foams and the rheology of the batter (Wilderjans *et al.*, 2013; Godefroidt *et al.*, 2019). Flours obtained from breads do not have the ability to form a gluten network and their starch does not have the ability to gelatinise, so they are not suitable, on their own, for making cakes. However, they can be incorporated in certain quantities.

Nevertheless, there is no previous study about the maximum amount of bread flour that can be introduced in the product without affecting its final quality,

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nor about the influence of its particle size. In this article, we analyse how replacing wheat flour by bread flour in sponge cakes and layer cakes, at different concentration levels (10, 20 and 30%) and particle sizes (200, 500 and 1000 μm) influences final quality. We further analyse its influence on the microstructure, density and viscosity of cake batter, as well as on the specific volume, texture and colour of the final product.

Materials and Methods

Materials

Several baguette breads (wheat, water, salt, yeast and malt) purchased at Carrefour supermarket (Palencia, Spain) were milled after 4 days staling at room temperature, with an ultra-centrifugal mill Retsch ZM 200 (Düsseldorf, Germany), and a milling speed of 14000 rpm. Distinct sieves (1000 μm, 500 μm and 200 μm mesh screen) were used to obtain different particle sizes. The moisture content of the three flours obtained were 9, 8.8 and 8.1 g 100 g^{-1}, respectively. Wheat flour (10.8 g 100 g^{-1} moisture; 8.98 g 100 g^{-1} protein) was supplied by Harina Castellana S.A. (Valladolid, Spain).

The other ingredients used were fluid whole milk (Central Lechera Asturiana, Siero, Spain), fresh eggs (local market, Spain), refined sunflower oil (Urzante, Navarra, Spain), baking powder (Puratos, Gerona, Spain), emulsifier SuperMixo T500 (Puratos, Gerona, Spain), white sugar (AB Azucarera Iberia, Valladolid, Spain), powdered milk (Nestlé Sveltesse, Barcelona, Spain) and local potable water.

Cake Elaboration

Cakes were prepared according to the formulation in Table 1. A professional mixer (KitchenAid, St. Joseph, MI, USA) was used to mix both formulations. For layer cakes, all the ingredients in the formulation were mixed at speed 4 (135 rpm) for 1 min and speed 6 (180 rpm) for 9 min with intermediate scraping. Wheat flour was replaced with 10, 20 and 30% of bread flour. Batter was portioned into oil-coated aluminium pans (109 × 159 × 38 mm) (185 g in each pan).

For sponge cakes, a creaming-mixing procedure was used. Sugar, egg, water and emulsifier were mixed for 2 min at speed 6 (180 rpm). Next, powdered milk, wheat flour and bread flour (10 and 20%) were added to the mixing process, which continued for 3 min at speed 8 (225 rpm). Batter was portioned into oil-coated aluminium pans (109 × 159 × 38 mm) (100 g in each pan).

Both, layer cakes and sponge cakes, were baked at 190 °C for 25 min in a preheated electric oven (Salva, Lezo, Spain). Cakes were left to cool for 60 min after baking and were then stored in properly closed plastic bags at 20 °C. A total of 10 formulations for layer cakes (Control [without bread flour], 200 μm 10%, 500 μm 10%, 1000 μm 10%, 200 μm 20%, 500 μm 20% 1000 μm 20%, 200 μm 30%, 500 μm 30% and 1000 μm 30%) and 7 formulations for sponge cakes (Control [without bread flour], 200 μm 10%, 500 μm 10%, 1000 μm 10%, 200 μm 20%, 500 μm 20% and 1000 μm 20%) were prepared. When preparing the 30% bread flour sponge cake formulation, the final cake volume and quality were too low and several analyses, such as texture, could not be performed, so this formulation was withdrawn from this study. Each formulation was performed in duplicate.

Batter Characteristics

A Rapid Visco Analyser (RVA-4) (Newport Scientific model 4-SA, Warriewood, Australia) was used to evaluate the batter viscosity. A 25 g of batter sample was analysed at 30 °C for 3 min by a stirring process at 160 rpm (Sahagún *et al*., 2018). In order to obtain density, the final batter was measured using an Elcometer 1800 pycnometer (Manchester, UK). For microstructure, we used a DM750 microscope (Leica Microsystems, Wetzlar, Germany) with a × 20 magnification combined with LAS-EZ software (Leica Microsystems, Wetzlar, Germany) to capture images. All the samples were performed in duplicates for each repetition.

Cake Specific Volume

The final volume of cakes was determined at a Volscan Profiler volume analyser (Stable Microsystems, Surrey, UK). The specific volume was calculated through the ratio of the volume and cake weight. All the analyses were performed in four cakes of each formulation for each repetition, 24 h after baking.

Texture Analysis

Texture was evaluated using a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK) with a 25-mm-diameter cylindrical aluminium probe. Samples were obtained using the central slide (2 cm thick) of four cakes for each repetition, after 24 h of storage. The tests were carried out using a texture profile analysis (TPA) and a 50% of depth penetration, a test speed of 2 mm s^{-1} and a delay of 30 s between the first and the second compressions. The TPA graphic provided the values for hardness, cohesiveness and resilience (Gómez *et al*., 2010).

Table 1 Cakes formulation (g $100g^{-1}$)

	Wheat flour	Bread flour	White sugar	Egg	Water	Powdered milk	Emulsifier	Milk	Sunflower oil	Baking powder
Sponge										
Control	245	-	240.5	344	55	25	14	-	-	-
10%	220.5	24.5	240.5	344	55	25	14	-	-	-
20%	196	49	240.5	344	55	25	14	-	-	-
Layer										
Control	350	-	315	175	-	-	-	210	105	10.5
10%	315	35	315	175	-	-	-	210	105	10.5
20%	280	70	315	175	-	-	-	210	105	10.5
30%	245	105	315	175	-	-	-	210	105	10.5

Crust and Crumb Colours

Crust colour was measured at two different points of the cake surface in four cakes of each batch (2 × 4 × 2). Crumb colour was evaluated at the central point of the central slices from four cakes of each batch (1 × 4×2). The analyses were carried out using a PCE-CSM 2 colorimeter (PCE Instruments, Meschede, Germany) with a D65 Illuminant with 2° Standard Observer. Values were expressed in the CIE L^* a^* b^* colour space.

Statistical Analysis

Statistical results were obtained using a Statgraphics Centurion XVI software (Statpoint Technologies, Warrenton, USA). All the results obtained were analysed for variance (ANOVA). Fisher's least significant difference (LSD) was used to describe means with 95% confidence intervals.

Results and Discussion

Batter Properties

The density and the viscosity of the sponge batters do not change when up to 20% of bread flour is incorporated (Table 2), regardless of the particle size of the flour. Despite the similarity in density values, Figure 1 shows that the increase in bread flour percentage and in particle size resulted in a reduction of the number of bubbles, as well as an increase in size. Flour particles, and specially starch, help stabilise the bubbles in the batter through a mechanism known as Pickering stabilisation (Godefroidt *et al.*, 2019). This type of stabilisation produces better results with smaller particle sizes (Román *et al.*, 2018). Therefore, flours with smaller particle size are preferable for sponge cake making (Moiraghi *et al.*, 2013). As the starch in bread flours has been pre-gelatinised (Varriano-Marston *et al.*, 1980) it seems that this change reduces its ability to stabilise foam, but not completely, and finer particle sizes are still preferable. Sahi (2008) indicated that not only was the amount of air incorporated important but also the way in which it was introduced, preferable in bubbles as small as possible. In fact, in this study, the increase in particle size reduces the stability of these foams, especially when the percentage is high, by increasing the size of the bubbles (Stauffer, 1990).

Table 2 Characteristics of batter and cakes

	Batter density (g ml^{-1})	Viscosity (cP)	Specific volume (ml g^{-1})
Sponge			
Control	0.388 ± 0.030a	5179 ± 914.996a	4.292 ± 0.063c
200 μm 10%	0.391 ± 0.005a	5784 ± 65.053a	2.702 ± 0.084a
500 μm 10%	0.375 ± 0.0007a	5301.5 ± 546.594a	3.630 ± 0.263b
1000 μm 10%	0.372 ± 0.0212a	5516 ± 41.012a	3.695 ± 0.0204b
200 μm 20%	0.389 ± 0.007a	5662 ± 274.357a	3.608 ± 0.021b
500 μm 20%	0.389 ± 0.015a	5506 ± 347.897a	2.950 ± 0.155a
1000 μm 20%	0.369 ± 0.012a	5189.5 ± 98.287a	2.664 ± 0.371a
Layer			
Control	1.034 ± 0.006b	4523.5 ± 441.942a	2.456 ± 0.002bc
200 μm 10%	0.686 ± 0.459a	6023.5 ± 208.597b	2.502 ± 0.026c
500 μm 10%	1.016 ± 0.018ab	5617 ± 374.767ab	2.345 ± 0.029ab
1000 μm 10%	1.031 ± 0.032b	5298.5 ± 54.447ab	2.488 ± 0.065c
200 μm 20%	1.001 ± 0.009ab	7487.5 ± 309.006 cd	2.514 ± 0.062c
500 μm 20%	1.018 ± 0.038ab	5862 ± 21.213ab	2.454 ± 0.017bc
1000 μm 20%	1.001 ± 0.002ab	5821 ± 12.727ab	2.465 ± 0.065bc
200 μm 30%	1.004 ± 0.028ab	7805 ± 1624.93d	2.283 ± 0.039a
500 μm 30%	0.992 ± 0.006ab	6639.5 ± 342.947bcd	2.320 ± 0.094a
1000 μm 30%	0.931 ± 0.085ab	6339 ± 636.396bc	2.398 ± 0.066abc

Values for the same parameter in the same column, and the same kind of cake, followed by different letters are significantly different ($P < 0.05$).

It may surprise the fact that the viscosity of the sponge batters does not increase with the incorporation of bread flours, since these have a greater water absorption capacity (Fernández-Peláez *et al.*, 2021). Nevertheless, when analysing only 20% additions it is observed that this effect is minimised and that it may also be offset by incorporating air into the batter (Chesterton *et al.*, 2011; Kalinga & Mishra, 2009).

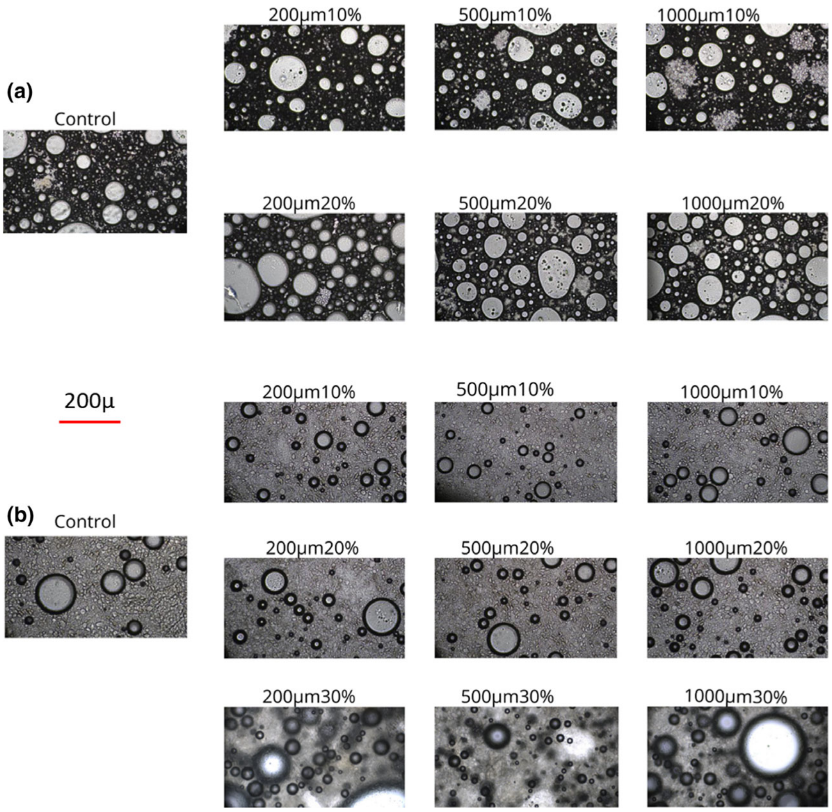

Figure 1 Microstructure of batter: sponge (a) and layer (b) batter

In the case of the layer batter density, significant differences are observed, compared to the control, only in the sample with 10% of the finest flour, which has a lower value. However, an increase in batter viscosity is observed as the percentage of bread flour increases. In the finest flours, this increase is significant from lower percentages (10%), but in coarser flours of more than 500 microns, it is significant only in the 30% of sample. This could explain why this effect is not observed in sponge, where the inclusion of 30% has not been analysed. It should also be considered that the weight of the flour in the total formula is less in the case of sponge cakes. The use of bread flour represents an increase in the amount of damaged starch. These damage starch granules compete with sucrose and proteins for water. This fact presumably limits the portion of water available for starch hydration and impacts on batter viscosity (Godefroidt *et al*., 2019). Regarding the distribution of the bubbles in the batter, the effect is not as clear as in the case of the sponge, but a blurred image is seen in the batter with 30% of bread flour. This blurring results from high viscosity that makes spreading of the batter on the sample holder difficult and, therefore, light cannot pass through it.

In layer cakes, the functionality of the flours is different from sponge cakes; flours do not help stabilise the bubbles, but they do help stabilise the emulsion by increasing the viscosity of the medium surrounding the dispersed particles (Wilderjans *et al*., 2013). However, excessive viscosity can be negative because it reduces expansion during baking (Lakshminarayan *et al*., 2006). Particle size is also important in this type of cakes (Gaines, 1985; Yamazaki & Donelson, 1972), among other things because of the higher water absorption capacity of finer flours. However, in the case of bread flours, this effect on water absorption is not observed (Fernández-Peláez *et al*., 2021), when there is excess water in the medium. Additionally, it has been shown that the importance of particle size is much greater in the case of sponge than in layers (Dhen *et al*., 2016).

Cake properties

In the case of sponge, a decrease in the specific volume is observed when bread flour is incorporated (Table 2), which in the worst case is close to 40%. This decrease is greater with the finest flours at 10% and with the thickest at 20%. However, in cakes, a drop is only observed in those having 20% of the flours greater than 500 microns, at the end of baking. This drop may be related to the role of starch in the formula. With starch gelatinisation, rheological values such as

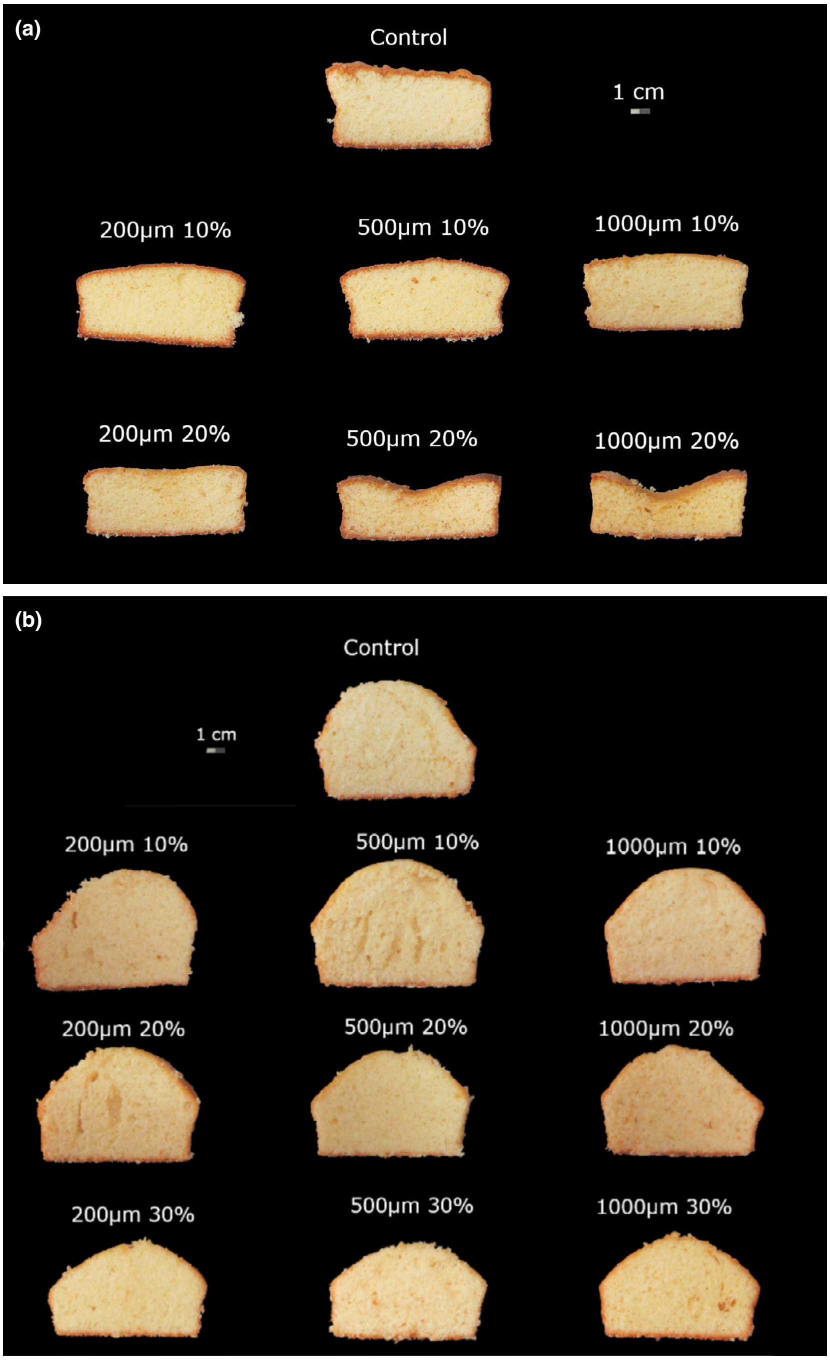

Figure 2 Slices of sponge (a) and layer (b) cakes with different particle sizes and percentages

the viscous and elastic component increase considerably, which helps give structure to the final cake and prevent its collapse (Donovan, 1977; Guy & Pithawala, 1981). However, for bread flours, where starch is pregelatinised, it largely loses the capacity to gelatinise (Fernández-Peláez *et al.*, 2021). Nevertheless, the lack of gelatinisation or the increase in viscosity during baking could also be related to the larger size of the bubbles present in the batter. These are more unstable when the surrounding solution is less viscous, which occurs before starch gelatinisation in baking (Godefroidt *et al.*, 2019), and facilitate the fall of the structure Figure 2. The greater effect on specific volume in coarser flours has also been observed by other researchers who analysed the effect of particle size in some flours in these kinds of sponge cakes (de la Hera *et al*., 2013; Dhen *et al*., 2016).

The incorporation of bread flour does not reduce the specific volume in percentages up to 20%, except for sponge cakes with 10% of intermediate flours, where a slight decrease is observed. However, at 30% a decrease in specific volume is observed, irrespective of the particle size used. It should be noted that this decrease is much smaller than in sponge, and in the most unfavourable case, it does not reach 8%. This decrease may be caused by the higher viscosity of the batter, due to the presence of gelatinised starch, as observed by Paesani *et al*. (2021) in their study of wholemeal maize flours. Higher viscosity hinders the expansion of the batter in baking (Gularte *et al*., 2012). As in the case of sponges, starch also plays a structural role when gelatinising in the support of the final structure, which can be hampered by the presence of bread flour. In contrast to sponge cakes, no volume drop is observed in the final stages of the process, indicating that the starch present in wheat flour is sufficient to achieve the necessary stability, even with the higher addition of bread flour.

The texture of sponge cakes with bread flour is generally harder and does not exhibit significant differences from those with 10% flour of more than 500 microns (Table 3). A clear relationship between specific volume and hardness is observed since the cakes with less specific volume are those with higher hardness values. This correlation has already been shown (Gómez *et al*., 2011) and it would explain the differences observed in hardness. It is also observed that the batters with the highest percentages of the coarsest flours are less cohesive, while no significant differences are observed between the resilience of the control and the bread flour cakes. The differences in cohesiveness may indicate that coarser flours make intermolecular attraction among ingredients more difficult, and thus, cakes tend to crumb, as already observed by de la Hera *et al*. (2013) in their analysis of rice flours. The final cakes were subjected to a sensory analysis, by focus group (see supplementary material), where the experts had also observed a lower cohesiveness of the cakes.

Table 3 Texture profile of the analysed cakes

	Hardness (N)	Cohesiveness	Resilience
Sponge			
Control	3.582 ± 0.277a	0.667 ± 0.024b	0.288 ± 0.015ab
200 μm 10%	9.671 ± 1.871c	0.638 ± 0.031b	0.287 ± 0.021ab
500 μm 10%	5.582 ± 1.755ab	0.672 ± 0.023b	0.297 ± 0.008b
1000 μm 10%	5.413 ± 0.996ab	0.663 ± 0.009b	0.293 ± 0.010b
200 μm 20%	7.499 ± 0.799bc	0.662 ± 0.010b	0.300 ± 0.007b
500 μm 20%	8.372 ± 0.435c	0.630 ± 0.020ab	0.2845 ± 0.012ab
1000 μm 20%	7.676 ± 0.719bc	0.581 ± 0.024a	0.252 ± 0.024a
Layer			
Control	7.414 ± 0.747a	0.669 ± 0.021a	0.295 ± 0.001a
200 μm 10%	6.837 ± 0.346a	0.687 ± 0.020a	0.323 ± 0.019a
500 μm 10%	6.656 ± 1.531a	0.715 ± 0.016a	0.519 ± 0.294b
1000 μm 10%	5.975 ± 0.523a	0.691 ± 0.053a	0.318 ± 0.033a
200 μm 20%	5.969 ± 0.116a	0.673 ± 0.017a	0.318 ± 0.015a
500 μm 20%	6.725 ± 0.262a	0.669 ± 0.035a	0.316 ± 0.032a
1000 μm 20%	6.930 ± 0.360a	0.676 ± 0.038a	0.316 ± 0.032a
200 μm 30%	6.854 ± 2.484a	0.759 ± 0.087a	0.401 ± 0.147a
500 μm 30%	6.797 ± 0.733a	0.699 ± 0.001a	0.308 ± 0.001a
1000 μm 30%	5.843 ± 2.218a	0.749 ± 0.111a	0.395 ± 0.160a

Values for the same parameter in the same column, and the same kind of cake, followed by different letters are significantly different ($P < 0.05$).

In turn, the texture of the layer is generally not affected by the addition of bread flours up to 30%. Although other authors have found correlations between specific volume and hardness (Gómez *et al*., 2011), in this study the differences in specific volume are narrow, and do not seem to be enough to become textural differences. It should also be considered that bread flours, as starch is pregelatinised, generate gels that are less hard than wheat flour (Fernández-Peláez *et al*., 2021), which could help to reduce the cake hardness. However, the percentage used is not sufficient for significant differences to be observed. Although no significant differences were observed in texture, in the sensory analysis (see supplementary material), a different and less pleasant mouthfeel was observed in the 30% bread flour addition, especially in those with flours of larger particle size.

Regarding cake colour, not very clear trends are observed (Table 4). Sponge cakes with the lowest volume also have crusts with lower values of a^*, and L^* stands out, although in the case of brightness, only the one with the highest percentage and the largest particle size shows significant differences with the control. On the other hand, in layer cakes, a* values increase only with the highest addition percentages (30%). In the case of the crumbs, no clear trend is observed for any of the samples. As is well known, the colour of the crust is influenced by the Maillard and the caramelisation of sugars (Purlis, 2010). The incorporation of bread flour, where starches are pregelatinised and therefore are more accessible to the action of hydrolytic enzymes, could have an influence. However, the low level of addition and the short time that elapses between batter preparation and baking, which means less time for enzyme activity, minimise these effects. In the case of crumbs, as the temperature does not exceed 100°C, colour is more influenced by the colour of the ingredients. Although bread flours have a somewhat darker colour than wheat flours and higher values of a^* and b^*, they do not have great differences,

Table 4 Colour parameters of the analysed cakes

	Crust				Crumb			
	L*	a*	b*	ΔE	L*	a*	b*	ΔE
Sponge								
Control	53.21 ± 2.00bc	20.70 ± 1.37d	32.01 ± 0.39ab		64.22 ± 4.45b	3.67 ± 0.97a	20.08 ± 1.10a	
200 μm 10%	42.22 ± 2.45abc	13.43 ± 2.35ab	26.77 ± 0.87ab	14.39 ± 0.36a	58.17 ± 4.14ab	5.04 ± 2.48a	25.80 ± 1.21c	8.98 ± 2.39ab
500 μm 10%	43.97 ± 8.39abc	16.86 ± 0.19bc	27.40 ± 4.85ab	11.44 ± 8.67a	62.89 ± 0.62ab	4.81 ± 1.77a	23.14 ± 2.16abc	3.62 ± 2.61a
1000 μm 10%	53.73 ± 6.49c	18.04 ± 1.56 cd	32.41 ± 3.05ab	5.87 ± 0.07a	64.29 ± 0.07b	4.30 ± 0.50a	22.54 ± 1.69abc	2.63 ± 1.46a
200 μm 20%	57.32 ± 1.57c	18.09 ± 1.56 cd	33.97 ± 0.54b	5.34 ± 1.77a	62.92 ± 5.26ab	4.78 ± 0.67a	20.76 ± 1.42ab	4.12 ± 1.71a
500μm20%	37.76 ± 10.82ab	13.92 ± 0.87ab	26.02 ± 4.90a	18.15 ± 11.16a	54.07 ± 5.82a	5.65 ± 1.53a	22.52 ± 1.31abc	10.97 ± 4.82b
1000μm20%	37.04 ± 8.24a	13.08 ± 1.44a	26.29 ± 3.14a	18.84 ± 8.61a	58.40 ± 1.88ab	5.19 ± 1.25a	24.07 ± 0.12bc	7.33 ± 1.30ab
Layer								
Control	70.95 ± 2.12b	11.63 ± 1.69abc	34.22 ± 2.09ab		72.70 ± 9.62bc	3.26 ± 0.43a	21.77 ± 4.30abcd	
200 μm 10%	68.63 ± 2.19b	10.39 ± 0.96a	32.02 ± 0.68a	3.53 ± 2.20a	61.56 ± 2.90a	4.16 ± 0.25abc	19.47 ± 0.12ab	11.43 ± 2.79abcd
500 μm 10%	61.77 ± 4.27ab	13.71 ± 1.36cde	35.49 ± 3.82ab	10.13 ± 10.11ab	68.59 ± 10.35abc	4.14 ± 0.18abc	23.77 ± 3.10abcd	8.40 ± 4.34abc
1000 μm 10%	62.22 ± 5.97ab	14.29 ± 1.41de	35.17 ± 2.66ab	9.78 ± 4.77ab	62.85 ± 2.04ab	3.59 ± 0.09ab	18.69 ± 1.40a	10.34 ± 2.37abcd
200 μm 20%	65.14 ± 1.99ab	11.02 ± 0.17ab	31.81 ± 0.72a	6.32 ± 2.12ab	57.87 ± 0.85a	4.59 ± 0.06c	19.35 ± 0.57a	15.10 ± 0.74d
500μm20%	67.96 ± 1.41b	11.69 ± 0.82abc	34.21 ± 0.74ab	3.11 ± 1.34a	58.91 ± 3.91a	4.64 ± 0.33c	19.85 ± 0.19abc	14.00 ± 3.84 cd
1000 μm 20%	55.56 ± 12.72a	12.78 ± 1.01bcd	31.52 ± 4.19a	15.86 ± 12.99b	60.18 ± 2.68a	4.60 ± 0.07c	19.40 ± 0.93a	12.82 ± 2.80bcd
200 μm 30%	68.01 ± 1.17b	14.55 ± 0.45de	38.74 ± 0.49b	6.18 ± 0.70ab	78.88 ± 0.38c	3.95 ± 0.35abc	24.93 ± 2.49bcd	7.18 ± 0.80ab
500 μm 30%	66.92 ± 2.43b	13.43 ± 0.54cde	37.36 ± 1.19b	5.43 ± 2.66ab	77.05 ± 0.92c	4.23 ± 0.86abc	25.28 ± 3.37 cd	6.14 ± 1.41a
1000 μm 30%	64.75 ± 1.41ab	15.38 ± 0.25e	38.13 ± 0.10b	8.25 ± 1.22ab	77.72 ± 0.71c	4.30 ± 0.77bc	25.77 ± 3.45d	6.89 ± 1.60a

L*: lightness; a*: green-red axis; b*: blue-yellow axis. Values for the same parameter in the same column, and the same kind of cake, followed by different letters are significantly different ($P < 0.05$)

especially in the case of crumbs (Fernández-Peláez *et al.*, 2021), the largest part in breads. This together with the low percentage incorporated make the effects on the colour of the internal part of the cakes unimportant.

Conclusions

The substitution of wheat flour for bread flour to reduce food waste in the production of cakes is possible in layer cakes but not in sponge cakes. In the former, it is possible to substitute between 20 and 30% without significantly modifying the properties of the cakes, while in sponge it is not possible to exceed 10%. Furthermore, layer cakes are less affected by particle size and require less effort in the milling process to incorporate bread flour, compared to sponge that would require bread flours of smaller particle size. New studies would be necessary to evaluate the possibility of reusing wasted bread in other elaborations based on flours.

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Author contribution

Priscila Guerra-Oliveira: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Investigation (equal); Methodology (equal); Writing – original draft (equal). **Mayara Belorio:** Data curation (equal); Methodology (equal); Visualization (equal). **Manuel Gomez:** Conceptualization (equal); Funding acquisition (equal); Methodology (equal); Project administration (equal); Supervision (equal); Visualization (equal); Writing – original draft (equal); Writing – review & editing (equal).

Ethical guidelines

Ethics approval was not required for this research.

Peer review

The peer review history for this article is available at https://publons.com/publon/10.1111/ijfs.15577.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

References

This reference is important because it offers data on the functionality of bread flours (used in this study) comparing them with those of wheat flours.

This reference is important because it explains the stabilization of foams through the pickering effect in bakery products, and the effect of the particle size.

This reference explains the changes that occur in the components of wheat flour in the baking process, and the changes in their functionality.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Supplementary Material

