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Effects of adding chickpea and chestnut flours to layer cakes

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Summary Chestnut and chickpea flours have interesting nutritional characteristics and can be incorporated into layer cake formulations. This study aims to evaluate the effect of incorporating mixtures of these flours with wheat flour in the elaboration of layer cakes. With this aim, layer cakes were elaborated with the three different flours. Mixes of 50% of these flours and a mixture of the three flours in the same proportion were analysed. Batter density, microstructure and viscosity, as well as the specific volume, texture and acceptability of layer cakes were evaluated. Chickpea flour reduced the batter density and increased viscosity compared to wheat flour, while chestnut flour reduced viscosity and did not clearly affect density. Although both flours produced layer cakes with lower specific volume, as well as less cohesive and springiness, the effect on specific volume was clearer in chestnut flour. With 50% of chickpea flour, it was possible to obtain layer cakes with the same specific volume and hardness as those made with wheat flour. Layer cake acceptability decreased with the reduction in wheat flour, regardless of the type of flour incorporated. No improved acceptability has been found when combining chickpea and chestnut flours.

Keywords Acceptability, baked product, batter, chestnut, pulse.

Introduction

In recent times, there has been a growing interest in the incorporation of flours with nutritional advantages into the elaboration of baked products. Studies on the incorporation of legume flours in cakes are extensive (Bravo-Nuñez & Gómez, 2021) as is the use of leftovers from fruit and vegetable processing (Gómez & Martinez, 2018).

Chestnut flour is characterised by its high content of sugars and resistant starch, as well as antioxidants and other bioactive compounds (de Vasconcelos *et al.*, 2010). The chestnut processing industry values whole chestnuts. However, in the process, part of the chestnuts breaks, constituting a by-product that can be reused after conversion into flour. Because of this, chestnut flour incorporation into breads and cookies has been proposed (Zhu, 2017). However, studies on the incorporation of chestnut flour in cakes are scarce, and are limited to the work of Yildiz & Dogan (2014), who analysed mixtures of chestnut flour, potato starch and hydrocolloids. In turn, legume flours have a high protein and fibre content; they are also a source of health-promoting antioxidants (Hall *et al.*, 2017). As in the case of chestnuts, when chickpea grains are processed, part of them break and are not suitable for commercialisation in form of whole grains or canned chickpeas. Therefore, the use of chickpea flour from these broken grains can be useful to take advantage as an industry by-product. However, the incorporation of legume flours reduces the acceptability of baked products (Bravo-Nuñez & Gómez, 2021), something that is related to the off-flavours that appear (Roland *et al.*, 2017).

Regrettably, in the literature, there is not much information about how to mask pulses off-flavours other than the traditional methods, namely adding sugars, salt, acids or aromas (Roland *et al.*, 2017). These authors also noted that most of the literature reports that, in relation to off-flavours, chickpea is the most suitable legume for substituting traditional ingredients such as wheat flour. Furthermore, Torra *et al.* (2021) observed that the combination of chickpea flour with reduced percentages of chestnut resulted in masking the off-flavours in cookies.

This study aims to analyse the effect of replacing wheat flour with chickpea and chestnut flours, and whether the use of their combinations can help increase the acceptability of layer cakes with these flours. For this purpose, layer cakes were elaborated with different mixes of chickpea flour (CPF), chestnut flour (CF) and wheat flour (WF). Batter density, viscosity and microstructure, as well as cake specific

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volume, weight loss, texture and acceptability, were evaluated.

Materials and methods

Materials

Layer cakes were elaborated using three different flours, wheat (WF), chestnut (CF) and chickpea (CPF) flours. Chestnut flour was supplied by Sortegel (Sortes, Portugal) and chickpea flour was provided by Molendum Ingredients (Zamora, Spain). These flours were previously sieved to obtain a fraction of less than 130 μm for each one. Wheat flour was supplied by Harinera Castellana (Valladolid, Spain); it was used without sieving. Other ingredients used were white sugar (AB Azucarera Iberia, Valladolid, Spain), fluid whole milk Únicla (Feiraco Lácteos S.L., Ames, La Coruña, Spain), pasteurised liquid eggs Ovopak (Alvarez Camacho S.L., Sevilla, Spain), refined sunflower oil (Remensol, Navarra, Spain) and baking powder (Puratos, Gerona, Spain).

Methods

Flour pasting properties

The pasting properties were studied using a Rapid Visco Analyser (RVA) (Model RVA-4C, Newport Scientific Pty. Ltd., Warriewood, Australia). 3.5 ± 0.01 g of the sample (dry basis) was dispersed in 25 ± 0.01 g of distilled water. The mixture was subjected to heating and to cooling cycles according to the AACC method 76-21.02 (AACC, 1997). Samples were analysed in duplicate.

Layer cake elaboration

Seven different layer cakes were made: one formulation was elaborated with 100% of wheat flour (WF100); another one with 100% of chestnut flour (CF100) and another with 100% of chickpea flour (CPF100). The rest of the layer cakes were produced with flour mixes using different proportions of WF, CF and CPF: 50%WF + 50%CF (WF50-CF50), 50% WF + 50%CPF (WF50-CPF50), 50%CF + 50%CPF (CF50-CPF50), and 33%WF + 33%CF + 33%CPF (WF33-CF33-CPF33).

White sugar (315 g) and flour (350 g) were first weighed in a bowl, followed by the liquid ingredients: fluid whole milk (210 g), sunflower oil (105 g) and pasteurised egg (175 g) which were weighted separately in another bowl. The baking powder (10.5 g) was added over the other ingredients at the end. All ingredients were mixed using a Kitchen Aid 5KPM50 mixer (Kitchen Aid, Benton Harbor, Michigan, USA) at a speed 6 for 1 min, followed by speed 4 for 9 min. Portions of 185 g of cake batter were placed in aluminium pans which were anointed previously with sunflower oil. Cakes were baked at 190 °C for 25 min. After 1 h, each cake was removed from its pan, packaged in plastic bags and stored for 24 h at 24 °C. All layer cakes were prepared in duplicate.

Cake batter properties

Batter density was obtained using an Elcometer 1800 pycnometer (Elcometer, Manchester, UK). Density was calculated as the relation of weight (g) of batter placed in the filled pycnometer and the volume capacity of the pycnometer. Samples were evaluated in duplicate for each elaboration.

Batter microstructure was examined with a DM750 microscope (Leica Microsystems, Wetzlar, Germany). A drop of the batter was placed on a microscope slide and covered with a coverslip. The slide was compressed under a constant weight (1 kg) to obtain a batter layer of uniform thickness. The images were taken with a Leica EC3 video camera incorporated to the microscope (Leica Microsystems, Heerbrugg, Switzerland).

Batter samples of 28 g were placed in aluminium cans to perform viscosity analysis using a Rapid Visco Analyser (RVA-4) (Newport Scientific model 4-SA, Warriewood, Australia). The test was performed with a constant temperature of 30 °C at 160 rpm for 4 min. The viscosity obtained at 3 min was considered the cake batter viscosity and the samples were evaluated in duplicate.

Cake characteristics

All the following cake characteristics were evaluated 24 h after baking:

- Weight loss was calculated as the difference between the value of the batter weight before baking and the cake sample. For each formulation, four cake samples were obtained and the weight loss of each formulation was calculated as the average value between the weight losses of these samples.
- Volume was evaluated using a Volscan Profiler volume analyser (Stable Microsystems, Surrey, UK). Specific volume for each cake was calculated considering the relation between the cake volume and the cake weight. An average value was calculated between the four cake samples for each formulation.
- Texture was evaluated through a texture profile analysis (TPA) test performed using a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK). The test was performed using a 25-mm-diameter cylindrical aluminium probe, at a test speed of 2 mm s^{-1} and a double compression at 50% of depth penetration with a 30 s delay between the first and the second compression. Pre- and post-test speed was 1 and 5 mm seg^{-1}, and a

5 kg cell load was used. Results of hardness, cohesiveness and springiness were calculated. The central slice (2 cm of thick) of four cakes of each elaboration was evaluated.

Acceptability test
Acceptability of WF100, WF50-CFF50, WF50-CPF50 and WF33-CF33-CPF33 was evaluated by 100 volunteers, who were between 16 and 65 years of age. Cakes were divided into pieces of 2 cm wide, coded with four-digit numbers and served in random order. One entire cake was presented to consumers for its appearance evaluation. Cakes were evaluated according to five attributes (visual appearance, odour, texture, taste and overall acceptability). This evaluation was carried out using a hedonic scale of 9 points, which ranged from "I like it very much" (9 score) to "I dislike it very much" (1 score).

Statistical analysis
The statistical analysis was conducted using Statgraphics Plus 5.1 software (Statpoint Inc., Warrenton, USA). The results were evaluated by analysis of variance (One-way ANOVA). Fisher's least significant difference (LSD) was used to describe the significant differences between the results with 95% confidence intervals.

Results and discussion

Flour pasting properties

As shown in Figure 1, wheat flour viscosity is higher than chestnut and chickpea flours, from the moment of starch gelatinisation. Among these other flours, chickpea flour has the lowest viscosity profile. Specifically, both the viscosity peak and the final viscosity are much higher in the case of wheat flour, and somewhat higher in chestnut flour than in chickpea flour. The viscosity after heating is determined by starch gelatinisation and the increase generated in this process (Balet *et al.*, 2019). For this reason, the differences between flours may be due to the lower starch content of chestnut and chickpea flours, with chestnut flour being richer in simple sugars, mainly sucrose (Miguelez *et al.*, 2004), and chickpea flour being richer in protein, lipids and fibre (Rachwal-Rosiak *et al.*, 2015) than wheat flour. This has already been observed in previous studies with chestnut flour (Zhou *et al.*, 2021) and with chickpea flour (Mohammed *et al.*, 2014; Bigne *et al.*, 2021). In the case of chickpea flour, less rise in viscosity after final cooling is also observed, related with a lower tendency to retrogradation. Retrogradation is usually associated with the percentage of amylose. The starch fraction is responsible for this phenomenon. However, it is also related to amylose characteristics, such as molecular weight (Román *et al.*, 2020), and would therefore indicate differences in this respect. Nevertheless, it is also possible that this less rise in viscosity after final cooling is only due to the lower starch content, a component that retrogrades and causes the final increase in viscosity during cooling.

Cake batter properties

The effect of the use of chestnut and chickpea flour in batter density and viscosity is shown in Table 1. Layer cakes with chickpea flour showed the lowest batter density and, therefore, a higher air incorporation. The incorporation of this flour into the various mixes reduced the density of the batters. This effect has already been observed by Gómez *et al.* (2008). In the case of chestnut batters, no significant differences were observed with wheat batters. However, chestnut flour incorporation in mixtures with wheat flour reduced batter density, although to a lesser extent than chickpea flour. On the other hand, batter viscosity was much higher in layer cakes with chickpea flour, and it increased as this flour was included in the mixtures. Chestnut batters viscosity was lower than in wheat batters. The increase in batter viscosity with legume flour incorporation has already been observed by Gularte *et al.* (2012) in gluten-free cakes, and may be related to their higher protein content. This effect, which has also been perceived with the incorporation of vegetable proteins, has been related to the higher water absorption capacity of these proteins (Sahagún *et al.*, 2018). On the contrary, in the case of chestnut flour, viscosity was lower since it had a higher sucrose content, and sucrose is soluble in water.

In terms of air bubbles distribution (Figure S1), the average size of the bubbles was greater as the amount of wheat flour was reduced. Nevertheless, this effect was not very clear in the 50% mixtures. It is known that the larger the average size of the bubbles, the greater their instability. This facilitates the coalescence phenomena and the escape of these gases from the batter during baking (Stauffer, 1990), reducing cake volume (Gómez *et al.*, 2011).

Cake characteristics

The specific volume (Table 1 and Figure S2) of wheat layer cakes was higher than the volume of the cakes elaborated with chickpea and chestnut flours. Concerning the flour blends, chestnut flour incorporation reduced specific volume more clearly than chickpea flour. The specific volume of cakes with wheat and chickpea flour blends at 50% or even those with blends of all flours (WF33-CF33-CPF33) – where 66%

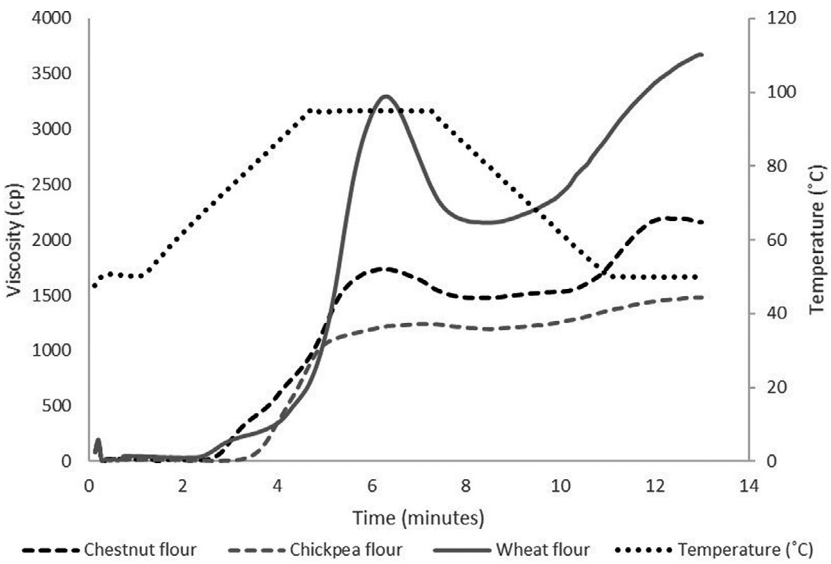

Figure 1 Pasting profile of flours used in layer cake elaborations.

Table 1 Characteristics of batter and layer cakes elaborated with different combinations of wheat flour (WF), chestnut flour (CF) and chickpea flour (CPF)

Sample	Density (g mL^{-1})	Viscosity (cp)	Specific volume (mL g^{-1})	Weight loss (%)
WF100	1.046 ± 0.021d	4408±14bc	2.443 ± 0.132d	8.25 ± 0.72ab
CF100	1.035 ± 0.001 cd	3764±130a	1.823 ± 0.128a	9.41 ± 0.47bc
CPF100	0.914 ± 0.008a	6076±29e	2.037 ± 0.157ab	8.24 ± 0.41ab
WF50-CF50	1.015 ± 0.007c	4295±211b	2.161 ± 0.025bc	9.65 ± 0.09c
W50-CPF50	0.959 ± 0.017b	4774±48d	2.413 ± 0.001 cd	7.66 ± 0.76a
CF50-CPF50	0.982 ± 0.002b	4751±8 cd	1.889 ± 0.080a	8.53 ± 0.89abc
WF33-CF33-CPF33	0.984 ± 0.006b	4355±58b	2.217 ± 0.126bcd	8.35 ± 0.18abc

Values with the same letter in the same column do not present significant differences ($P < 0.05$).

of flour corresponds to wheat and chickpea – was not significantly different from that of wheat cake. The reduction in volume with the addition of chickpea flour has already been observed in previous studies (Bravo-Nuñez & Gómez, 2021) and has been attributed to the larger particle size of these flours. The negative effect of larger particle size has already been proven in studies with wheat flour (Gaines, 1985) or pulse flour (de la Hera *et al.*, 2012). Yet, in this study, only particles smaller than 130 μm were used to reduce particle size. Perhaps, for this reason, the results with the 50% mixtures were better than those observed in other studies. Specific volume reduction with chickpea flour has also been attributed to the higher protein content and the lower starch content. Therefore, less changes in batter rheology occur during baking due to gelatinisation (increase in G' and G") and these changes are necessary to stabilise the structure (Wilderjans *et al.*, 2013). This negative effect of high protein content in layer cakes has also been demonstrated with the incorporation of protein-rich fractions from micronised pea flour (Gómez *et al.*, 2012), or directly from legume proteins (Sahagún *et al.*, 2018). In addition, the larger average bubble size mentioned above does not help achieve a high specific volume.

Regarding chestnut cakes, no work has been published except for Yildiz & Dogan (2014), where chestnut flour and potato starch were mixed, and it was observed that the higher the amount of chestnut flour, the lower the cake volume. However, these results are not comparable to our study due to the differences in formulation. It is not easy to explain the lower specific volume of these cakes since multiple factors are involved. Handleman *et al.* (1961) found a relationship between batter density, viscosity and surface tension and the resulting cake characteristics. Nevertheless, among these factors, batter viscosity is what most differentiates the products made with chestnut flour, so it could be the reason for these low volumes. To obtain a better volume, the addition of gums, which increase the viscosity of the batter, could be used (Yildiz & Dogan, 2014).

Concerning weight loss, layer cakes made with chestnut flour presented the highest values, although differences from the rest of the cakes are under 1.5%. In general, layer cakes with lower specific volume have lower weight loss values (de la Hera *et al.*, 2013) due to the lower surface area (Zhou & Therdthai, 2008). Nonetheless, this did not occur in chestnut flour cakes which not only had a lower specific volume but also presented a higher weight loss. Both legume protein (Bravo-Nuñez & Gómez, 2019) and gelatinised starch (Belorio *et al.*, 2020) have a high water absorption capacity, especially when compared to ungelatinised starch or other soluble components. In the case of chickpea flour, the lower starch content and, therefore, the gelatinised starch in the final product may be compensated by its higher protein content. But in the case of chestnut flour, the lower content of these components may be the reason for the greater weight loss during baking and subsequent cooling.

Table 2 shows the effect of adding chestnut and chickpea flour to cake texture parameters. Previous studies have found a negative correlation between the specific volume of cakes and their hardness (Aydogdu *et al.*, 2018); in this case, a similar trend is observed in the case of wheat and chickpea flour mixtures. Thus, the hardness of chickpea flour layer cakes with lower specific volume was higher than those with wheat flour. However, in the 50% mixtures (WF50-CPF50) with a specific volume similar to the control, hardness was also similar. Nevertheless, no significant differences were observed between layer cakes made with chestnut flour, which had a specific volume clearly lower than wheat cake. The lower starch content of chestnut flour may produce this effect since starch is mainly responsible for crumb texture after retrogradation (Román *et al.*, 2021). Yet, the high sugar content of these flours may also play a role as sugar reduces retrogradation (Wang *et al.*, 2016).

It is also noteworthy that layer cakes elaborated with chickpea or chestnut flour had a lower cohesiveness and a lower springiness than those made with wheat flour. The reduction in cohesiveness has already been observed in other studies where wheat flour is replaced by gluten-free flours (Gómez *et al.*, 2008, 2012; de la Hera *et al.*, 2012). In commercial gluten-free cakes, the egg or egg white percentage used is higher to minimise this effect (Belorio & Gómez, 2020). Therefore, the reduction in cohesiveness may be related to the lower gluten content of these flours and the effect of these proteins on the cohesiveness of the batters after baking.

Table 2 Textural parameters of layer cakes elaborated with different combinations of wheat flour (WF), chestnut flour (CF) and chickpea flour (CPF)

Sample	Hardness (N)	Springiness	Cohesiveness
WF100	9.37 ± 0.81ab	0.977 ± 0.039b	0.644 ± 0.034c
CF100	10.10 ± 0.52bc	0.854 ± 0.031a	0.412 ± 0.015a
CPF100	11.90 ± 0.10d	0.898 ± 0.088ab	0.421 ± 0.006a
WF50-CF50	10.70 ± 0.33bcd	0.854 ± 0.022a	0.537 ± 0.033b
W50-CPF50	8.47 ± 0.76a	0.885 ± 0.039ab	0.564 ± 0.031b
CF50-CPF50	9.43 ± 0.84ab	0.822 ± 0.021a	0.430 ± 0.013a
WF33-CF33-CPF33	10.86 ± 0.34 cd	0.854 ± 0.004a	0.466 ± 0.017a

Values with the same letter in the same column do not present significant differences ($P < 0.05$).

Acceptability

After physical measurements, wheat flour cakes and cakes elaborated with mixtures of wheat and the other flours at 50% and 33% were chosen for consumer evaluation (Table 3). Wheat layer cakes were the best rated in terms of overall acceptability. As the content of non-conventional flours increased, acceptability decreased and it was even lower in the case of the mixture of all flours with a low percentage of wheat flour. Reduced acceptability of layer cakes with the incorporation of legume flour is common (Bravo-Nuñez & Gómez, 2021). This is mainly due to lower acceptability values for texture and flavour when wheat flour is reduced. In 50% of the blends, it was observed that the addition of chickpea flour reduced taste rating, while chestnut flour had a more negative effect on appearance. The latter seems to be related to the smaller volume of chestnut flour layer cakes and their darker colour (Figure S2), which is different from the usual colours of wheat cake, both externally and internally. However, only a reduction of approximately 1 point (on a scale of 1 to 9) in overall acceptability was observed in these 50% mixes; the ratings obtained for these cakes were quite positive. Previous studies on the use of chickpea and chestnut flour blends in cookie elaboration showed a positive effect of these mixtures. This was because chestnut flour allowed masking the typical flavours of chickpea flour, usually less appreciated by consumers (Torra *et al.*, 2021). This is in agreement with Roland *et al.* (2017), who indicated that the presence of sweet flavours can mask pulses off-flavours. However, in our case, this effect was not observed and the flavours of these flours, which are foreign to a layer cake, reduced its acceptability. This indicates that the various modifications to components, such as starch gelatinisation, produced in the elaboration of layer cakes, or the different formulation ingredients, influence the organoleptic quality of the products obtained.

Conclusion

The replacement of wheat flour by chickpea or chestnut flour in layer cake elaboration generates products

Table 3 Consumer test results of layer cakes elaborated with different combinations of wheat flour (WF), chestnut flour (CF) and chickpea flour (CPF)

Sample	Appearance	Odour	Texture	Taste	Overall acceptability
WF100	8.11 ± 0.88b	7.35 ± 1.42b	7.81 ± 1.08c	7.71 ± 1.20d	7.82 ± 0.99c
WF50-CF50	6.25 ± 1.60a	7.03 ± 1.65b	7.07 ± 1.44b	6.74 ± 1.75c	6.88 ± 1.41b
WF50-CPF50	8.31 ± 0.91b	7.01 ± 1.49b	7.32 ± 1.40b	6.10 ± 2.06b	6.89 ± 1.68b
WF33-CF33-CPF33	6.11 ± 1.46a	6.26 ± 1.75a	6.54 ± 1.91a	5.18 ± 2.09a	5.76 ± 1.74a

Values with the same letter in the same column do not present significant differences ($P < 0.05$).

with lower specific volume, lower cohesiveness and lower acceptability. The negative effect on volume is more pronounced with chestnut flour. In contrast to cookies (Torra *et al.*, 2021), the mixture of chestnut and chickpea flours does not show advantages in the acceptability of the layer cakes obtained.

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Conflicts of interest

There are no conflicts of interest.

Ethical guidelines

The sensory evaluation was performed according to a protocol previously approved by the Committee of Tests and Research from Hospital Rio Carrión (Palencia, Spain).

Author contribution

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

Peer review

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Data availability statement

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

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Supporting Information

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

Figure S1. Photomicrograph of cake batters with different wheat (WF), chestnut (CF) and chickpea (CPF) flours mixtures.

Figure S2. Cross-section of cakes with different wheat (WF), chestnut (CF) and chickpea (CPF) flours mixtures.