STUDIES ON CAKE QUALITY MADE OF
WHEAT-CHICKPEA FLOUR BLENDS

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Abstract

Legume flours, due to their amino acid composition and fibre content are ideal ingredients for improving the nutritional value of bread and bakery products. In this study the influence of the total or partial replacement of wheat flour by chickpea flour on the quality characteristics of two kinds of cake was analyzed. The effects of the chickpea variety and the milling system were also considered. Volume, symmetry, chroma, and crust and crumb L* diminished when increasing the amount of chickpea flour. The replacement of wheat flour by chickpea flour also induced an increase in the initial firmness but cohesiveness and resilience diminished, increasing the tendency to hardening. The chickpea variety and the milling process (white or whole flour) had also significant influence on cake quality.

Key words: composite flours, chickpea, cake quality, texture properties, staling.
1. Introduction

Pulses have been at the heart of many traditional cuisines for thousands of years. Legumes have been known as “a poor man’s meat”. They supply protein, complex carbohydrates, fibre and essential vitamins and minerals to the diet, are low in fat and sodium and contain no cholesterol. Legumes have been identified as low glycaemic index foods (Bornet, Billaux & Messing, 1997). Selecting foods of low glycaemic index is very important in the dietary treatment of diabetes mellitus, increases satiety, facilitates the control of food intake and has other health benefits for healthy subjects in terms of post-prandial glucose and lipid metabolism (Rizkalla, Bellisle & Slama, 2002). Regular consumption of pulses may have important protective effects on risk for cardiovascular disease (Anderson & Major, 2002). Moreover, pulses contain a rich variety of compounds, which, if consumed in sufficient quantities, may help to reduce tumour risk (Mathers, 2002). In fact, most health organizations encourage their frequent consumption (Leterme, 2002). These nutritional benefits are related to the reduced digestibility of legume starch and dietary fibre content of legumes, mainly located in their husk fractions. The low digestibility of legume starch has been attributed to its amylose, which is considerably branched and of high molecular weight (Tharanathan & Mahadevamma, 2003).

In the last decades, attitudes and perceptions towards legumes have been changing, bringing about a revival of interest on the part of consumers (Morrow, 1991). The annual per capita consumption of pulses in 1999 was 5.9 kg worldwide, and 2.8 kg in Europe. These consumption figures rose by 10% from 1989 to 1999 but they could increase even further if the food industry and professional organizations take up the challenge to incorporate grain legumes in
novel, convenient and healthy food products (Schneider, 2002). The addition of
legume to cereal-based products could be a good alternative for increasing the
intake of legumes. In addition, legume proteins are rich in lysine and deficient in
sulphur containing amino acids, whereas cereal proteins are deficient in lysine,
but have adequate amounts of sulphur amino acids (Eggum & Beame, 1983).
Therefore, the combination of grain with legume proteins would provide better
overall essential amino acid balance, helping to combat the world protein calorie
malnutrition problem (Livingstone, Feng & Malleshi, 1993).
Several studies about the influence of the addition of legume flours on the
functional properties of bread dough and final bread quality have been reported in
the last 30 years. Among the legumes tested, it is worth mentioning the addition of
chickpea flour (Singh, Harinder, Sekhon & Kaur, 1991; Dodok, Ali, Hozová,
Halasová & Polacek, 1993; Iyer & Singh, 1997), germinated chickpea flour
(Fernandez & Berry, 1989), germinated pea flour (Sadowska, Blaszczak, Fornal,
Vidal-Valverde & Frias, 2003), lupin flour (Campos & El-Dash, 1978; Lucisano
& Pompei, 1981; Dervas, Doxastakisk, Hadjisavva-Zinoviadi, & Triantafillakos,
1999; Doxastakis, Zafiriadis, Irakli, & Tananaki, 2002; Pollard, Stoddard,
Popineau, Wrigley & MacRitchie, 2002), fermented lentil flour (Sadowska,
Fornal, Vidal-Valverde & Frias, 1999), lentil and bean flours (Finney, Morad &
Hubbard, 1980; Morad, Leung, Hsu & Finney, 1980; Shehata, Darwish, El-Nahry
& Andel-Razek, 1988; Lorimer, Zabik, Harte, Stachiw & Uebersax, 1991) to
wheat flour for obtaining bread. However, despite the good results obtained with
bread, those studies have not been extended to other cereal baked products.
The aim of this study was to determine the effect of the partial or complete replacement of wheat flour by chickpea flour on the quality of cakes. The effect of the chickpea variety and the milling process was also tested.

2. Materials and methods

2.1 Materials

Cake flour (9.8% protein) was supplied by *Harinera Castellana* S.A., Medina del Campo (Spain); sucrose, sunflower oil, milk, fresh whole eggs, emulsifier and double-action baking powder, were purchased from the local market. Chickpeas were supplied by Alimentos Naturales S.A., León (Spain) and milled in a stone mill in Harinera Los Pisones, Zamora (Spain). After milling, the flour with particle size lower than 210 µm was referred as white chickpea flour; and the coarse fraction was ground again in a laboratory mill (3100, Perten Instruments, Sweden). The flour from the second milling was blended with the white chickpea flour in order to obtain the whole chickpea flour.

2.2 Proximate analysis of flours

Wheat and chickpea flours were analysed following the AACC methods (2000) for moisture (method 44-15A), crude protein (method 46-13), crude fat (method 30-25), crude fiber (method 32-10) and ash (method 08-01).

2.3 Pasting properties of flours

The Rapid ViscoTM Analyser (RVA) (Newport Scientific Pty Ltd, Australia) was used to determine the pasting properties of the chickpea flours. Pasting properties
were determined following the standard Newport Scientific Method 1 (STD1). The heating cycle was 50 °C to 95 °C in 282 s, holding at 95 °C for 150 s and then cooling to 50 °C. Each cycle was initiated by a 10-second mixing at 960 rpm paddle speed, and 160 rpm paddle speed was used for the rest of the test. The RVA studies were carried out using 3.0 g of sample and 25 ml water in an aluminium canister. The parameters recorded were peak viscosity (PV), trough or hot paste viscosity (HPV), final or cool paste viscosity (CPV), breakdown (PV-HPV), and setback (CPV-HPV). Flour samples were run in triplicate.

2.4 Cake preparation

Two kinds of cakes were elaborated: a layer cake (Cake A), and a sponge cake (Cake B). The recipes used are described in Table 1. In layer cake elaboration, a single-bowl mixing procedure was used. All ingredients were mixed during 10 min at speed 6 using a Kitchen–Aid Professional mixer (KPM5). 200 grams of cake batter were placed into 120 mm diameter and 45 mm height, metallic, lard coated pan, and were baked in an electric oven for 25 min at 200°C.

In the sponge cake making, a creaming mixing procedure was used. All ingredients, except for the flour and milk, were mixed during 2 min at speed 6 using a Kitchen–Aid Professional mixer (KPM5). After the addition of the milk and the flour, the mixing process continued during 3 min at speed 8. 150 grams of cake batter were placed into pans and baked as described above.

Two sets of twelve cakes were prepared from each batter. After baking, the cakes were removed from the pans and left one hour for cooling; then, they were placed on coded white plastic plates, and sealed with plastic wraps to prevent drying. Eight cakes from the same batter were used for physical measurements, and four for texture evaluation after seven and 14 days of storage.
2.5 Physical Measurements

Batter density was determined with a measuring cylinder and expressed as the relation between the weight of batter and the same volume of distilled water.

Cake quality attributes included: volume, determined by seed displacement, weight, symmetry and volume index, measured following the AACC method 10–91 (AACC, 2000). A digital calibre was used to measure the cake heights.

Measurements were run in triplicate.

Colour was measured using a Minolta spectrophotometer CN-508i (Minolta, Co.LTD, Japan). Results were expressed in the CIE L*a*b* colour space and were obtained using the D65 standard illuminant, and the 2° standard observer.

The hue angle (tan⁻¹(b*/a*)) and chroma or intensity ((a*²+b*²)¹/²) of the cakes’ crumb and crust were calculated. Colour determinations were made 5x5 times in each cake: crumb or crust cake colour was checked at five different points on each cake and every point was measured five times. The five points were positioned in the centre of the cake and in the centre of four imaginary sectors in which it was divided along the diameter.

Crumb texture was determined by a TA-XT2 texture analyzer (Stable Microsystems, Surrey, UK) provided with the software “Texture Expert”. An Aluminium 25 mm diameter cylindrical probe was used in a “Texture Profile Analysis” double compression test (TPA) to penetrate to 50% depth, at 2 mm/s speed test, with a 30 s delay between first and second compression. Firmness (N), chewiness (N), cohesiveness, springiness and resilience were calculated from the TPA graphic (Gómez, Ronda, Caballero, Blanco & Rosell, 2007). In cake texture
determinations, the crust was removed, and samples of 40x40x20 were used. Averaged results of eight determinations are presented.

2.6 Statistical analysis
In order to assess significant differences among samples, it was performed a multiple comparison analysis of samples using the program Statistica (99 Edition, 5.5 Version, StatSoft Inc.). Fisher’s least significant differences (LSD) test was used to describe means with 95% confidence.

3. Results and discussion

3.1 Proximate composition of flours
The chemical composition of the diverse flours is detailed in Table 2. The chickpea flours had significantly (p<0.05) higher content of protein, fat, ash and fibre than the wheat flour. Protein content of chickpea flours ranged from 22.48 to 25.18g /100g, and crude fat values showed a wide variation, being comprised between 3.81 to 7.22 g/100g. No significant differences were found between the chickpea flours, and regarding the variety, Pedrosillano was the most different variety because of its higher moisture and protein content and its lower fat content.

3.2 Thermal behaviour of the wheat flour and the different chickpea flours
Viscometric parameters of the different chickpea flours were determined by using the RVA (Table 3). When a chickpea flour-water dispersion was heated, an increase in the apparent viscosity was observed due to the gelatinization of the
starch, although the peak viscosity induced by these type of flours (877-1032 cP) was lower than the one promoted by the wheat flour (2621 cP). Chickpea flours resulted in pastes with lower peak viscosity, holding strength, breakdown, final viscosity and total setback than the wheat flour; this is likely due to their lower carbohydrate content (Table 2), and also their different protein content could affect the viscometric parameters (Morris, King & Rubenthaler, 1997). Very low breakdown was observed in the chickpea flours, ranging from 38 cP to 68 cP, in comparison with 893 cP obtained with the wheat flour. The breakdown is related to the ability of the starches to withstand heating at high temperature and shear stress, usually high values of breakdown are associated to high peak viscosities in cereals such as wheat, barley, millet, rye and sorghum (Ragaee & Abdel-Aal, 2006), although different behaviour has been observed in triticale (León, Barrera, Pérez, Ribotta & Rosell, 2005). When temperature decreased, an increase in viscosity was observed but chickpea flour induced lower viscosity during cooling than wheat flour. The increase in viscosity is related to the ability of the amylose chains to reassociate and form a gel and it is referred to as setback. Taking into account the low setback values obtained with chickpea flours, it could be expected that the replacement of wheat flour by chickpea flours would result in softer crumbs. No tendency was observed concerning the type of chickpea flour (whole or white), or chickpea cultivar.

3.3 Effect of chickpea flours on cake shape and size

In Table 4 the effect of composite flours containing chickpea flours on batter density and on cake volume and shape can be observed. The replacement of wheat
flour for increasing amounts of chickpea flours decreased batter density when 
recipe A was used. Conversely, in recipe B, the presence of chickpea flour 
decreased air incorporation in the batter, yielding lower density. In both recipes, 
the whole composite flours resulted in high density batters, decreasing the air 
incorporation. Regarding chickpea cultivars, Pedrosillano gave the greatest batter 
density in recipe A, whereas Lechoso and Sinaloa brought about the highest batter 
density in recipe B.

It could have been expected that lower batter density would result in higher cake 
volume, as was the case with sponge cakes, but, in fact, the opposite phenomenon 
was observed in layer cakes. Handleman, Conn & Lyons (1961) found a 
relationship between batter density, viscosity and surface tension and the resulting 
cake characteristics, although some other parameters like the amount of gas, from 
the whipping process or from chemical leavening, entrapped into the batter, and 
the gas kept during baking affected cake quality.

Cake volume diminished as the chickpea flour percentage increased in both (A 
and B) cakes, especially in cake A. Cake B does not incorporate baking powder in 
its formulation, whilst cake A does. During the baking process, baking powder 
generates gases, which should be retained in order to guarantee good cake 
volume, and in that respect flour quality has an important role to play. Another 
important factor is the gelatinization temperature of the flour, as Miller & Trimbo 
(1965), Howard, Hughes, & Strobel (1968) and Howard (1972) pointed out for 
layer cakes, whereas Mizukoshi, Kawada & Matsui (1979) and Mizukoshi, Maeda 
& Amano (1980) reached the same conclusion for sponge cakes. The starch 
gelatinization at low temperatures would prevent the correct expansion of doughs.
As can be observed in Table 3, chickpea flours presented lower peak viscosity than wheat flours, thus lower gas retention and lower expansion of the product could be expected. Chickpea flours also presented higher protein content, and different amino acid composition than wheat flours which could affect cake characteristics, especially volume (Mohamed, Lajis & Hamid, 1995; Mohamed, S., & Hamid, N.A., 1998). As far as chickpea cultivars are concerned, Sinaloa and Lechoso gave cakes with higher volume, in both the A and B cakes, although in the latter no significant differences were found between Pedrosillano and Lechoso.

As for cake weight, no significant differences were found. Therefore, the water retention capacity was not affected by the substitution of wheat flour for chickpea flour, or by the kind of chickpea flour in sponge cakes. Amongst chickpea cultivars, small differences were also detected, but they could not be attributed to their different chemical composition.

The volume index is an indicator of cake volume and, as expected, followed a similar tendency to volume. Symmetry indicates the differences in height between the central zone and the lateral zone. Thus, a high symmetry suggests that cakes mainly rise in their central part, while a negative symmetry indicates that cake volume falls down at the end of the baking process. Hence, symmetry gives an idea about gas retention in the final baking phase. In both cases the incorporation of chickpea flour reduced their symmetry, and in the case of the A cakes with 100% of chickpea flour it became negative. This result supports the idea that cakes elaborated with chickpea flour had worse gas retention capacity during baking than those lacking legume flour, especially during the last baking phase.
The kind of chickpea flour exerted lower effect on symmetry, although the white flours had higher symmetry in sponge cakes, and thus, higher gas retention and higher final volume than layer cakes. In the case of layer cakes, small differences were observed, the whole flours produced cakes with the highest symmetry. The differences between the various chickpea cultivars were minimal in sponge cakes. In layer cakes, cultivars Lechoso and Sinaloa, the most similar in composition, generated cakes with the highest symmetry and final volume.

3.4 Effect of chickpea flours on cake colour

Crust colour in cakes varied with the quantity, the kind and the variety of chickpea flour (Table 5). This influence was more important in layer than in sponge cakes. The crust colour data of cakes are shown in table 5. Layer cakes became darker (lower L*) as the chickpea flour quantity increased. Pedrosillano also resulted in dark cakes. With regard to the kind of chickpea flour, whole flour produced brighter cakes. The hue angle indicates the tone; values near 0 indicate reddish tones whilst values near 90 indicate yellowish tones. Meanwhile, chroma values near 0 indicate subdued colours, whilst high chroma values indicate vivacious colours. The effect of the composite flours on the hue and chroma values was more evident in sponge cakes, where as the quantity of chickpea increased, the chroma and the hue were reduced. Chickpea cultivars had also an influence on these parameters, on both kinds of cakes, although this effect was more important in the A cakes. The crust colour of cakes, was generated in the baking process due to the Maillard reactions between sugars and amino acids, and the caramelization process of sugars. Therefore, the differences observed when
the quantity of chickpea flour increased could be attributed to the high protein
content and the different amino acid composition of the composite flours
compared to the wheat flour. Differences between layer and sponge cakes seemed
to result from their different formulations.

Cake crumb does not reach temperatures above 100ºC, so the Maillard or
caramelization reactions by sugars fail to take place. Therefore, crumb colour
must be the result of the raw materials colours and their interactions. The crumb
colour data of cakes are shown in table 5. Cake A crumb was lightly darker than
cake B crumb, and the chickpea flour addition reduced its luminosity, but this
effect was only significant in the B cakes. Differences between chickpea cultivars
were hardly observed. The greatest differences in crumb colour were observed in
chroma, which increased as the amount of chickpea flour increased, and were
more noticeable in the A cakes. In both cases, cakes elaborated with Pedrosillano
flour presented the highest chroma, mainly due to the highest b* value. This effect
was expected because of the more intense orange colour of Pedrosillano flours.
Whole flours had the highest a* value and the lowest hue value in both kinds of
cakes, but the effect of the kind of flour on b* and chroma values was minimum
and different depending on the type of cake. These results agree with those
obtained by Dodok et al. (1993), who observed that chickpea flour triggered the
change in the crumb colour when they studied the addition of chickpea flour to
bread doughs.

3.5 Influence of chickpea flours on cake texture
In table 6 the textural characteristics data can be observed. The influence of flours on the initial firmness was inversely proportional to cake volume. Therefore, the initial firmness increased when the percentage of chickpea flour increased, although this trend was not significant in layer cakes when 50% of chickpea flour was used to replace wheat flour. These results agree with those obtained by Guinot & Mathlouthi (1991), who observed that small additions of soy protein increased the firmness of sponge cakes. The cakes elaborated with whole flour were firmer than those elaborated with white flour, being this difference more important in sponge cakes. The differences between chickpea cultivars were only significant in layer cakes, where the cakes elaborated with Lechoso and Sinaloa were less firm than those elaborated with Pedrosillano.

The volume and the firmness of the A cakes presented a negative correlation, with an $r^2$ of 29.53. However, the $r^2$ increased up to 85.41 when samples containing 100% whole flour from cultivars Lechoso and Sinaloa were removed from this correlation. Whole cakes from these cultivars presented similar firmness than those obtained with cultivars Andaluz and Pedrosillano, but with higher cake volume. Cultivars Lechoso and Sinaloa had lower protein and water content but it could not be concluded that the chemical composition was responsible for the higher volume with a similar firmness. In the case of the B cakes, a negative correlation was observed between volume and firmness, with an $r^2$ of 45.16.

Among the other textural parameters, layer cakes were the most influenced by the composite flours. Cohesiveness decreased when the percentage of chickpea flour increased, but it was not affected by the kind and cultivar of chickpea. Gumminess and chewiness were lower in white flour cakes and with cultivars
Lechoso and Sinaloa. Adhesiveness was higher in cakes containing 100% chickpea flour and from cultivar Andaluz, although it did not present significant differences with Pedrosillano. Both springiness and resilience diminished when the chickpea flour percentage increased, whilst Lechoso and Sinaloa varieties presented the highest resilience values. In general, a similar behaviour between Lechoso and Sinaloa varieties versus Andaluz and Pedrosillano was observed, which resulted in cakes with higher firmness, gumminess and adhesiveness, but lower resilience.

In sponge cakes, as the percentage of chickpea flour increased, cohesiveness and resilience decreased, while gumminess, chewiness and adhesiveness increased. White flours produce less cohesive, more gummy and chewy, and with less resilience cakes. The chickpea variety had only a significant effect on cohesiveness, being cultivars Andaluz and Pedrosillano the ones that produced the most cohesive cakes.

Firmness trends over the storage time can be seen in figure 1, A (recipe A), and B (recipe B). The influence of chickpea cultivar on the firmness trend was not significant in any case. In cake A samples, no great differences in firmness increase pertaining to the composite flours were appreciated, although cakes elaborated with white chickpea flour stale more slowly than those elaborated with whole flour or with wheat flour. In cakes elaborated with 50% of both flours a gradual increase in firmness was observed, whilst in those elaborated with 100% of wheat or chickpea flour a higher firmness increase during the first week was observed, firming slightly slower in the second one. The effect of the composite flours was much evident in the B cakes, where as the percentage of chickpea flour
increased, in both white and whole flour, the cakes hardened more quickly. After 14 days of storage, the B cakes elaborated with whole chickpea flour presented similar firmness to those elaborated with white flour, however their initial firmness was higher and thus the total firmness increase was lower. Unlike bread staling phenomena, hardening phenomena in cakes have been scarcely studied but it is known that these products develop complex systems, where several ingredients interact with each other and affect texture (Gelinas, Roy & Guillet, 1999). In general, hardening phenomena in cakes are attributed to crumb dehydration (Willhoft, 1973), which was avoided in this study by packaging the cakes, and to starch retrogradation (Gujral, Rosell, Sharma & Singh 2003).

In conclusion, the addition of 50% of chickpea flour would improve the nutritional value of cakes without greatly affecting their quality characteristics. Lechoso and Sinaloa would be the most adequate cultivars for enrichment, and white better than whole flour. Sponge cake quality was less affected by the chickpea addition than layer cakes, probably because of the lower flour percentage in its formula.

4. Acknowledgements

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5. References


Figure 1: Effect of the composite flours on the firmness of cakes during storage.

A: Cakes obtained from recipe A. B: Cakes obtained from recipe B.
Figure 1. A.

Figure 1. B.
Table 1: Cake formulations

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>A Cake</th>
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<th>B Cake</th>
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<td></td>
<td>(g)</td>
<td>%</td>
<td>(g)</td>
<td>%</td>
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<td>Flour</td>
<td>700</td>
<td>27.5</td>
<td>490</td>
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<td>378</td>
<td>14.9</td>
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<tr>
<td>Oil</td>
<td>210</td>
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<td>28</td>
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<td>Baking powder</td>
<td>21</td>
<td>0.8</td>
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Table 2: Proximate composition (g/100g) of wheat and chickpea flours

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<tr>
<th>Kind of flour</th>
<th>Chickpea Cultivar</th>
<th>Moisture</th>
<th>Crude protein</th>
<th>Crude fat</th>
<th>Crude fibre</th>
<th>Ash</th>
<th>Carbohydrates (by difference)</th>
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<td>10.81d</td>
<td>13.73a</td>
<td>1.40a</td>
<td>0.16a</td>
<td>0.78a</td>
<td>73.12c</td>
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<td>Andaluz</td>
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<td>24.65e</td>
<td>7.22f</td>
<td>1.36c</td>
<td>3.27b</td>
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<td>8.02b</td>
<td>23.46cd</td>
<td>6.26d</td>
<td>1.14b</td>
<td>3.31b</td>
<td>57.81b</td>
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<td></td>
<td>Pedrosillano</td>
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<td>25.18f</td>
<td>4.62c</td>
<td>1.37c</td>
<td>3.46d</td>
<td>56.90ab</td>
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<td>8.02b</td>
<td>23.09c</td>
<td>6.34de</td>
<td>1.41c</td>
<td>3.27b</td>
<td>57.87b</td>
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<td>Andaluz</td>
<td>7.98b</td>
<td>23.63d</td>
<td>6.87ef</td>
<td>2.72e</td>
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<td>55.50a</td>
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<td>23.06c</td>
<td>6.76e</td>
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<td>24.93ef</td>
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<td>2.78f</td>
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<td>22.48b</td>
<td>6.58e</td>
<td>2.64d</td>
<td>3.44d</td>
<td>57.60b</td>
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Different letters in the same column are significantly different (P<0.05)
Table 3. Viscometric parameters of different flours during cooking and cooling determined by the Rapid Visco Analyser.

<table>
<thead>
<tr>
<th>Kind of flour</th>
<th>Chickpea cultivar</th>
<th>Peak viscosity</th>
<th>Peak Time</th>
<th>Pasting Temperature</th>
<th>Holding strength</th>
<th>Breakdown</th>
<th>Total Setback</th>
<th>Final Viscosity</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>cP</td>
<td>min</td>
<td>ºC</td>
<td>cP</td>
<td>cP</td>
<td>cP</td>
<td>cP</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>2621 e</td>
<td>6.3 b</td>
<td>50.1 a</td>
<td>1728 e</td>
<td>893 c</td>
<td>1485 c</td>
<td>3213 e</td>
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<tr>
<td>White chickpea</td>
<td>Andaluz</td>
<td>954 b</td>
<td>5.9 a</td>
<td>79.1 d</td>
<td>888 b</td>
<td>66 b</td>
<td>258 a</td>
<td>1146 b</td>
</tr>
<tr>
<td></td>
<td>Lechoso</td>
<td>877 a</td>
<td>6.1 a</td>
<td>76.7 c</td>
<td>817 a</td>
<td>60 b</td>
<td>249 a</td>
<td>1066 a</td>
</tr>
<tr>
<td></td>
<td>Pedrosillano</td>
<td>1001 c</td>
<td>6.4 b</td>
<td>79.8 d</td>
<td>963 d</td>
<td>38 a</td>
<td>247 a</td>
<td>1210 c</td>
</tr>
<tr>
<td></td>
<td>Sinaloa</td>
<td>978 c</td>
<td>5.9 a</td>
<td>72.6 b</td>
<td>930 c</td>
<td>48 a</td>
<td>281 b</td>
<td>1211 c</td>
</tr>
<tr>
<td>Whole chickpea</td>
<td>Andaluz</td>
<td>936 b</td>
<td>6.9 c</td>
<td>79.1 d</td>
<td>887 b</td>
<td>49 a</td>
<td>279 b</td>
<td>1166 b</td>
</tr>
<tr>
<td></td>
<td>Lechoso</td>
<td>1032 d</td>
<td>5.9 a</td>
<td>76.0 c</td>
<td>964 d</td>
<td>68 b</td>
<td>300 b</td>
<td>1264 d</td>
</tr>
<tr>
<td></td>
<td>Pedrosillano</td>
<td>976 c</td>
<td>6.7 c</td>
<td>76.0 c</td>
<td>935 c</td>
<td>41 a</td>
<td>285 b</td>
<td>1220 c</td>
</tr>
<tr>
<td></td>
<td>Sinaloa</td>
<td>987 c</td>
<td>6.7 c</td>
<td>75.9 c</td>
<td>919 c</td>
<td>68 b</td>
<td>275 b</td>
<td>1194 c</td>
</tr>
</tbody>
</table>

Different letters in the same column are significantly different (P<0.05)
Table 4: Physical characteristics of batters and cakes

<table>
<thead>
<tr>
<th>Kind of flour</th>
<th>Batter density</th>
<th>Volume (cm³)</th>
<th>Weight (g)</th>
<th>Simetry</th>
<th>Volume Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
</tr>
<tr>
<td>Wheat flour / Chickpea flour</td>
<td>100 / 0</td>
<td>1.05c</td>
<td>0.51a</td>
<td>397.50c</td>
<td>465.00c</td>
</tr>
<tr>
<td></td>
<td>50 /50</td>
<td>0.98b</td>
<td>0.58b</td>
<td>373.90b</td>
<td>455.31b</td>
</tr>
<tr>
<td></td>
<td>0/100</td>
<td>0.94a</td>
<td>0.60c</td>
<td>348.75a</td>
<td>434.69a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>0.95a</td>
<td>0.58a</td>
<td>360.16a</td>
<td>469.06b</td>
<td>185.50b</td>
</tr>
<tr>
<td>Whole</td>
<td>0.96b</td>
<td>0.60b</td>
<td>362.50a</td>
<td>420.94a</td>
<td>184.13a</td>
</tr>
<tr>
<td>Chickpea cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andaluz</td>
<td>0.96b</td>
<td>0.62c</td>
<td>324.38a</td>
<td>418.75a</td>
<td>185.13cd</td>
</tr>
<tr>
<td>Lechosho</td>
<td>0.96b</td>
<td>0.57a</td>
<td>398.13b</td>
<td>453.13bc</td>
<td>183.63a</td>
</tr>
<tr>
<td>Pedrosillano</td>
<td>0.94a</td>
<td>0.60b</td>
<td>324.38a</td>
<td>448.13b</td>
<td>184.63bc</td>
</tr>
<tr>
<td>Sinaloa</td>
<td>0.98c</td>
<td>0.57a</td>
<td>388.75b</td>
<td>460.00c</td>
<td>185.88d</td>
</tr>
</tbody>
</table>

Different letters in the same column are significantly different (P<0.05)
Table 5: Crust and crumb colour of cakes

<table>
<thead>
<tr>
<th>Kind of flour</th>
<th>Crust</th>
<th>Crumb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L*</td>
<td>a*</td>
</tr>
<tr>
<td></td>
<td>A Cake</td>
<td>B Cake</td>
</tr>
<tr>
<td>Wheat flour / Chickpea flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 / 0</td>
<td>50.13c</td>
<td>44.03a</td>
</tr>
<tr>
<td>50 / 50</td>
<td>44.77b</td>
<td>46.17b</td>
</tr>
<tr>
<td>0 / 100</td>
<td>38.82a</td>
<td>45.05a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>40.46a</td>
<td>44.15a</td>
</tr>
<tr>
<td>Whole</td>
<td>43.14b</td>
<td>47.08b</td>
</tr>
<tr>
<td>Chickpea Cultivar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andaluz</td>
<td>43.87b</td>
<td>44.46a</td>
</tr>
<tr>
<td>Lechoso</td>
<td>42.53b</td>
<td>44.72a</td>
</tr>
<tr>
<td>Pedrosillano</td>
<td>36.60a</td>
<td>46.35b</td>
</tr>
<tr>
<td>Sinaloa</td>
<td>44.19b</td>
<td>46.92b</td>
</tr>
</tbody>
</table>

Different letters in the same column are significantly different (P<0.05)
<table>
<thead>
<tr>
<th>Kind of flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
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<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
<th>Wheat flour / Chickpea flour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
<td>B Cake</td>
<td>A Cake</td>
</tr>
<tr>
<td>Wheat flour / Chickpea flour</td>
<td>100 / 0</td>
<td>4.38a</td>
<td>3.62a</td>
<td>0.68c</td>
<td>0.76c</td>
<td>2.98ab</td>
<td>2.74a</td>
<td>2.62b</td>
<td>2.45a</td>
<td>0.05b</td>
<td>0.09a</td>
<td>0.88c</td>
<td>0.89a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td>50 /50</td>
<td>4.67a</td>
<td>5.66b</td>
<td>0.56b</td>
<td>0.72b</td>
<td>2.59a</td>
<td>4.02b</td>
<td>2.06a</td>
<td>3.67a</td>
<td>0.11b</td>
<td>0.10a</td>
<td>0.80b</td>
<td>0.91a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td>0/100</td>
<td>7.12b</td>
<td>8.65c</td>
<td>0.47a</td>
<td>0.61a</td>
<td>3.35b</td>
<td>5.16c</td>
<td>2.36b</td>
<td>4.53b</td>
<td>0.41a</td>
<td>0.12a</td>
<td>0.71a</td>
<td>0.88a</td>
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<tr>
<td>Kind of flour</td>
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<td>5.54a</td>
<td>5.70a</td>
<td>0.51a</td>
<td>0.69b</td>
<td>2.76a</td>
<td>3.87a</td>
<td>2.07a</td>
<td>3.47a</td>
<td>0.25a</td>
<td>0.08a</td>
<td>0.75a</td>
<td>0.90a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td>Whole</td>
<td>6.25b</td>
<td>8.61b</td>
<td>0.52a</td>
<td>0.63a</td>
<td>3.18b</td>
<td>5.31b</td>
<td>2.36b</td>
<td>4.73b</td>
<td>0.27a</td>
<td>0.08a</td>
<td>0.75a</td>
<td>0.89a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td>Andaluz</td>
<td>6.15ab</td>
<td>7.15a</td>
<td>0.52a</td>
<td>0.67b</td>
<td>3.16b</td>
<td>4.61a</td>
<td>2.36bc</td>
<td>4.11a</td>
<td>0.43a</td>
<td>0.09a</td>
<td>0.75a</td>
<td>0.90a</td>
</tr>
<tr>
<td>Kind of flour</td>
<td>Lechoso</td>
<td>5.22a</td>
<td>7.74a</td>
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<td>0.65a</td>
<td>2.62a</td>
<td>4.81a</td>
<td>1.96a</td>
<td>4.30a</td>
<td>0.17b</td>
<td>0.08a</td>
<td>0.75a</td>
<td>0.90a</td>
</tr>
<tr>
<td>Kind of flour</td>
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<td>6.97b</td>
<td>6.98a</td>
<td>0.51a</td>
<td>0.67b</td>
<td>3.44b</td>
<td>4.61a</td>
<td>2.53c</td>
<td>4.11a</td>
<td>0.27ab</td>
<td>0.07a</td>
<td>0.75a</td>
<td>0.89a</td>
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<tr>
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<td>6.73a</td>
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<td>4.33a</td>
<td>2.00ab</td>
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<td>0.18b</td>
<td>0.05a</td>
<td>0.75a</td>
<td>0.90a</td>
</tr>
</tbody>
</table>

Different letters in the same column are significantly different (P<0.05)