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**STUDIES ON CAKE QUALITY MADE OF
WHEAT-CHICKPEA FLOUR BLENDS**

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17 **Abstract**

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

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31 **Key words:** composite flours, chickpea, cake quality, texture properties, staling.

32 **1. Introduction**

33 Pulses have been at the heart of many traditional cuisines for thousands of years.
34 Legumes have been known as “a poor man’s meat”. They supply protein, complex
35 carbohydrates, fibre and essential vitamins and minerals to the diet, are low in fat
36 and sodium and contain no cholesterol. Legumes have been identified as low
37 glycaemic index foods (Bornet, Billaux & Messing, 1997). Selecting foods of low
38 glycaemic index is very important in the dietary treatment of diabetes mellitus,
39 increases satiety, facilitates the control of food intake and has other health benefits
40 for healthy subjects in terms of post-prandial glucose and lipid metabolism
41 (Rizkalla, Bellisle & Slama, 2002). Regular consumption of pulses may have
42 important protective effects on risk for cardiovascular disease (Anderson &
43 Major, 2002). Moreover, pulses contain a rich variety of compounds, which, if
44 consumed in sufficient quantities, may help to reduce tumour risk (Mathers,
45 2002). In fact, most health organizations encourage their frequent consumption
46 (Leterme, 2002). These nutritional benefits are related to the reduced digestibility
47 of legume starch and dietary fibre content of legumes, mainly located in their husk
48 fractions. The low digestibility of legume starch has been attributed to its
49 amylose, which is considerably branched and of high molecular weight
50 (Tharanathan & Mahadevamma, 2003).

51 In the last decades, attitudes and perceptions towards legumes have been
52 changing, bringing about a revival of interest on the part of consumers (Morrow,
53 1991). The annual per capita consumption of pulses in 1999 was 5.9 kg
54 worldwide, and 2.8 kg in Europe. These consumption figures rose by 10% from
55 1989 to 1999 but they could increase even further if the food industry and
56 professional organizations take up the challenge to incorporate grain legumes in

57 novel, convenient and healthy food products (Schneider, 2002). The addition of
58 legume to cereal-based products could be a good alternative for increasing the
59 intake of legumes. In addition, legume proteins are rich in lysine and deficient in
60 sulphur containing amino acids, whereas cereal proteins are deficient in lysine,
61 but have adequate amounts of sulphur amino acids (Eggum & Beame, 1983).
62 Therefore, the combination of grain with legume proteins would provide better
63 overall essential amino acid balance, helping to combat the world protein calorie
64 malnutrition problem (Livingstone, Feng & Malleshi, 1993).

65 Several studies about the influence of the addition of legume flours on the
66 functional properties of bread dough and final bread quality have been reported in
67 the last 30 years. Among the legumes tested, it is worth mentioning the addition of
68 chickpea flour (Singh, Harinder, Sekhon & Kaur, 1991; Dodok, Ali, Hozová,
69 Halasová & Polacek, 1993; Iyer & Singh, 1997), germinated chickpea flour
70 (Fernandez & Berry, 1989), germinated pea flour (Sadowska, Blaszcak, Fornal,
71 Vidal-Valverde & Frias, 2003), lupin flour (Campos & El-Dash, 1978; Lucisano
72 & Pompei, 1981; Dervas, Doxastakisk, Hadjisavva-Zinoviadi, & Triantafillakos,
73 1999; Doxastakis, Zafiriadis, Irakli, & Tananaki, 2002; Pollard, Stoddard,
74 Popineau, Wrigley & MacRitchie, 2002), fermented lentil flour (Sadowska,
75 Fornal, Vidal-Valverde & Frias, 1999), lentil and bean flours (Finney, Morad &
76 Hubbard, 1980; Morad, Leung, Hsu & Finney, 1980; Shehata, Darwish, El-Nahry
77 & Andel-Razek, 1988; Lorimer, Zabik, Harte, Stachiw & Uebersax, 1991) to
78 wheat flour for obtaining bread. However, despite the good results obtained with
79 bread, those studies have not been extended to other cereal baked products.

80 The aim of this study was to determine the effect of the partial or complete
81 replacement of wheat flour by chickpea flour on the quality of cakes. The effect of
82 the chickpea variety and the milling process was also tested.

83

84 **2. Materials and methods**

85 2.1 Materials

86 Cake flour (9.8% protein) was supplied by *Harinera Castellana S.A.*, Medina del
87 Campo (Spain); sucrose, sunflower oil, milk, fresh whole eggs, emulsifier and
88 double-action baking powder, were purchased from the local market.

89 Chickpeas were supplied by Alimentos Naturales S.A., León (Spain) and milled in
90 a stone mill in Harinera Los Pisones, Zamora (Spain). After milling, the flour with
91 particle size lower than 210 μm was referred as white chickpea flour; and the
92 coarse fraction was ground again in a laboratory mill (3100, Perten Instruments,
93 Sweden). The flour from the second milling was blended with the white chickpea
94 flour in order to obtain the whole chickpea flour.

95

96 2.2 Proximate analysis of flours

97 Wheat and chickpea flours were analysed following the AACC methods (2000)
98 for moisture (method 44-15A), crude protein (method 46-13), crude fat (method
99 30-25), crude fiber (method 32-10) and ash (method 08-01).

100

101 2.3 Pasting properties of flours

102 The Rapid ViscoTM Analyser (RVA) (Newport Scientific Pty Ltd, Australia) was
103 used to determine the pasting properties of the chickpea flours. Pasting properties

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

112 2.4 Cake preparation

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

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

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

129

130 2.5 Physical Measurements

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

133 Cake quality attributes included: volume, determined by seed displacement,
134 weight, symmetry and volume index, measured following the AACC method 10 –
135 91 (AACC, 2000). A digital calibre was used to measure the cake heights.
136 Measurements were run in triplicate.

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

140 The hue angle ($\tan^{-1}(b^*/a^*)$) and chroma or intensity ($((a^{*2}+b^{*2})^{1/2})$) of the cakes'
141 crumb and crust were calculated. Colour determinations were made 5x5 times in
142 each cake: crumb or crust cake colour was checked at five different points on each
143 cake and every point was measured five times. The five points were positioned in
144 the centre of the cake and in the centre of four imaginary sectors in which it was
145 divided along the diameter.

146 Crumb texture was determined by a TA-XT2 texture analyzer (Stable
147 Microsystems, Surrey, UK) provided with the software "*Texture Expert*". An
148 Aluminium 25 mm diameter cylindrical probe was used in a "*Texture Profile*
149 *Analysis*" double compression test (TPA) to penetrate to 50% depth, at 2 mm/s
150 speed test, with a 30 s delay between first and second compression. Firmness (N),
151 chewiness (N), cohesiveness, springiness and resilience were calculated from the
152 TPA graphic (Gómez, Ronda, Caballero, Blanco & Rosell, 2007). In cake texture

153 determinations, the crust was removed, and samples of 40x40x20 were used.
154 Averaged results of eight determinations are presented.

155

156 2.6 Statistical analysis

157 In order to assess significant differences among samples, it was performed a
158 multiple comparison analysis of samples using the program Statistica (99 Edition,
159 5.5 Version, StatSoft Inc.). Fisher's least significant differences (LSD) test was
160 used to describe means with 95% confidence.

161

162 3. Results and discussion

163 3.1 Proximate composition of flours

164 The chemical composition of the diverse flours is detailed in Table 2. The
165 chickpea flours had significantly ($p < 0.05$) higher content of protein, fat, ash and
166 fibre than the wheat flour. Protein content of chickpea flours ranged from 22.48 to
167 25.18g /100g, and crude fat values showed a wide variation, being comprised
168 between 3.81 to 7.22 g/100g. No significant differences were found between the
169 chickpea flours, and regarding the variety, Pedrosillano was the most different
170 variety because of its higher moisture and protein content and its lower fat
171 content.

172

173 3.2 Thermal behaviour of the wheat flour and the different chickpea flours

174 Viscometric parameters of the different chickpea flours were determined by using
175 the RVA (Table 3). When a chickpea flour-water dispersion was heated, an
176 increase in the apparent viscosity was observed due to the gelatinization of the

177 starch, although the peak viscosity induced by these type of flours (877-1032 cP)
178 was lower than the one promoted by the wheat flour (2621 cP). Chickpea flours
179 resulted in pastes with lower peak viscosity, holding strength, breakdown, final
180 viscosity and total setback than the wheat flour; this is likely due to their lower
181 carbohydrate content (Table 2), and also their different protein content could
182 affect the viscometric parameters (Morris, King & Rubenthaler, 1997). Very low
183 breakdown was observed in the chickpea flours, ranging from 38 cP to 68 cP, in
184 comparison with 893 cP obtained with the wheat flour. The breakdown is related
185 to the ability of the starches to withstand heating at high temperature and shear
186 stress, usually high values of breakdown are associated to high peak viscosities in
187 cereals such as wheat, barley, millet, rye and sorghum (Ragae & Abdel-Aal,
188 2006), although different behaviour has been observed in triticale (León, Barrera,
189 Pérez, Ribotta & Rosell, 2005). When temperature decreased, an increase in
190 viscosity was observed but chickpea flour induced lower viscosity during cooling
191 than wheat flour. The increase in viscosity is related to the ability of the amylose
192 chains to reassociate and form a gel and it is referred to as setback. Taking into
193 account the low setback values obtained with chickpea flours, it could be expected
194 that the replacement of wheat flour by chickpea flours would result in softer
195 crumbs. No tendency was observed concerning the type of chickpea flour (whole
196 or white), or chickpea cultivar.

197

198 3.3 Effect of chickpea flours on cake shape and size

199 In Table 4 the effect of composite flours containing chickpea flours on batter
200 density and on cake volume and shape can be observed. The replacement of wheat

201 flour for increasing amounts of chickpea flours decreased batter density when
202 recipe A was used. Conversely, in recipe B, the presence of chickpea flour
203 decreased air incorporation in the batter, yielding lower density. In both recipes,
204 the whole composite flours resulted in high density batters, decreasing the air
205 incorporation. Regarding chickpea cultivars, Pedrosillano gave the greatest batter
206 density in recipe A, whereas Lechoso and Sinaloa brought about the highest batter
207 density in recipe B.

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

215 Cake volume diminished as the chickpea flour percentage increased in both (A
216 and B) cakes, especially in cake A. Cake B does not incorporate baking powder in
217 its formulation, whilst cake A does. During the baking process, baking powder
218 generates gases, which should be retained in order to guarantee good cake
219 volume, and in that respect flour quality has an important role to play. Another
220 important factor is the gelatinization temperature of the flour, as Miller & Trimbo
221 (1965), Howard, Hughes, & Strobel (1968) and Howard (1972) pointed out for
222 layer cakes, whereas Mizukoshi, Kawada & Matsui (1979) and Mizukoshi, Maeda
223 & Amano (1980) reached the same conclusion for sponge cakes. The starch
224 gelatinization at low temperatures would prevent the correct expansion of doughs.

225 As can be observed in Table 3, chickpea flours presented lower peak viscosity
226 than wheat flours, thus lower gas retention and lower expansion of the product
227 could be expected. Chickpea flours also presented higher protein content, and
228 different amino acid composition than wheat flours which could affect cake
229 characteristics, especially volume (Mohamed, Lajis & Hamid, 1995; Mohamed,
230 S., & Hamid, N.A., 1998). As far as chickpea cultivars are concerned, Sinaloa and
231 Lechoso gave cakes with higher volume, in both the A and B cakes, although in
232 the latter no significant differences were found between Pedrosillano and
233 Lechoso.

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

239 The volume index is an indicator of cake volume and, as expected, followed a
240 similar tendency to volume. Symmetry indicates the differences in height between
241 the central zone and the lateral zone. Thus, a high symmetry suggests that cakes
242 mainly rise in their central part, while a negative symmetry indicates that cake
243 volume falls down at the end of the baking process. Hence, symmetry gives an
244 idea about gas retention in the final baking phase. In both cases the incorporation
245 of chickpea flour reduced their symmetry, and in the case of the A cakes with
246 100% of chickpea flour it became negative. This result supports the idea that
247 cakes elaborated with chickpea flour had worse gas retention capacity during
248 baking than those lacking legume flour, especially during the last baking phase.

249 The kind of chickpea flour exerted lower effect on symmetry, although the white
250 flours had higher symmetry in sponge cakes, and thus, higher gas retention and
251 higher final volume than layer cakes. In the case of layer cakes, small differences
252 were observed, the whole flours produced cakes with the highest symmetry. The
253 differences between the various chickpea cultivars were minimal in sponge cakes.
254 In layer cakes, cultivars Lechoso and Sinaloa, the most similar in composition,
255 generated cakes with the highest symmetry and final volume.

256

257 3.4 Effect of chickpea flours on cake colour

258 Crust colour in cakes varied with the quantity, the kind and the variety of
259 chickpea flour (Table 5). This influence was more important in layer than in
260 sponge cakes. The crust colour data of cakes are shown in table 5. Layer cakes
261 became darker (lower L*) as the chickpea flour quantity increased. Pedrosillano
262 also resulted in dark cakes. With regard to the kind of chickpea flour, whole flour
263 produced brighter cakes. The hue angle indicates the tone; values near 0 indicate
264 reddish tones whilst values near 90 indicate yellowish tones. Meanwhile, chroma
265 values near 0 indicate subdued colours, whilst high chroma values indicate
266 vivacious colours. The effect of the composite flours on the hue and chroma
267 values was more evident in sponge cakes, where as the quantity of chickpea
268 increased, the chroma and the hue were reduced. Chickpea cultivars had also an
269 influence on these parameters, on both kinds of cakes, although this effect was
270 more important in the A cakes. The crust colour of cakes, was generated in the
271 baking process due to the Maillard reactions between sugars and amino acids, and
272 the caramelization process of sugars. Therefore, the differences observed when

273 the quantity of chickpea flour increased could be attributed to the high protein
274 content and the different amino acid composition of the composite flours
275 compared to the wheat flour. Differences between layer and sponge cakes seemed
276 to result from their different formulations.

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

294

295 3.5 Influence of chickpea flours on cake texture

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

307 The volume and the firmness of the A cakes presented a negative correlation, with
308 an r^2 of 29.53. However, the r^2 increased up to 85.41 when samples containing
309 100% whole flour from cultivars Lechoso and Sinaloa were removed from this
310 correlation. Whole cakes from these cultivars presented similar firmness than
311 those obtained with cultivars Andaluz and Pedrosillano, but with higher cake
312 volume. Cultivars Lechoso and Sinaloa had lower protein and water content but it
313 could not be concluded that the chemical composition was responsible for the
314 higher volume with a similar firmness. In the case of the B cakes, a negative
315 correlation was observed between volume and firmness, with an r^2 of 45.16.

316 Among the other textural parameters, layer cakes were the most influenced by the
317 composite flours. Cohesiveness decreased when the percentage of chickpea flour
318 increased, but it was not affected by the kind and cultivar of chickpea.
319 Gumminess and chewiness were lower in white flour cakes and with cultivars

320 Lechoso and Sinaloa. Adhesiveness was higher in cakes containing 100%
321 chickpea flour and from cultivar Andaluz, although it did not present significant
322 differences with Pedrosillano. Both springiness and resilience diminished when
323 the chickpea flour percentage increased, whilst Lechoso and Sinaloa varieties
324 presented the highest resilience values. In general, a similar behaviour between
325 Lechoso and Sinaloa varieties versus Andaluz and Pedrosillano was observed,
326 which resulted in cakes with higher firmness, gumminess and adhesiveness, but
327 lower resilience.

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

334 Firmness trends over the storage time can be seen in figure 1, A (recipe A), and B
335 (recipe B). The influence of chickpea cultivar on the firmness trend was not
336 significant in any case. In cake A samples, no great differences in firmness
337 increase pertaining to the composite flours were appreciated, although cakes
338 elaborated with white chickpea flour stale more slowly than those elaborated with
339 whole flour or with wheat flour. In cakes elaborated with 50% of both flours a
340 gradual increase in firmness was observed, whilst in those elaborated with 100%
341 of wheat or chickpea flour a higher firmness increase during the first week was
342 observed, firming slightly slower in the second one. The effect of the composite
343 flours was much evident in the B cakes, where as the percentage of chickpea flour

344 increased, in both white and whole flour, the cakes hardened more quickly. After
345 14 days of storage, the B cakes elaborated with whole chickpea flour presented
346 similar firmness to those elaborated with white flour, however their initial
347 firmness was higher and thus the total firmness increase was lower. Unlike bread
348 staling phenomena, hardening phenomena in cakes have been scarcely studied but
349 it is known that these products develop complex systems, where several
350 ingredients interact with each other and affect texture (Gelinas, Roy & Guillet,
351 1999). In general, hardening phenomena in cakes are attributed to crumb
352 dehydration (Willhoft, 1973), which was avoided in this study by packaging the
353 cakes, and to starch retrogradation (Gujral, Rosell, Sharma & Singh 2003).

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

360

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366

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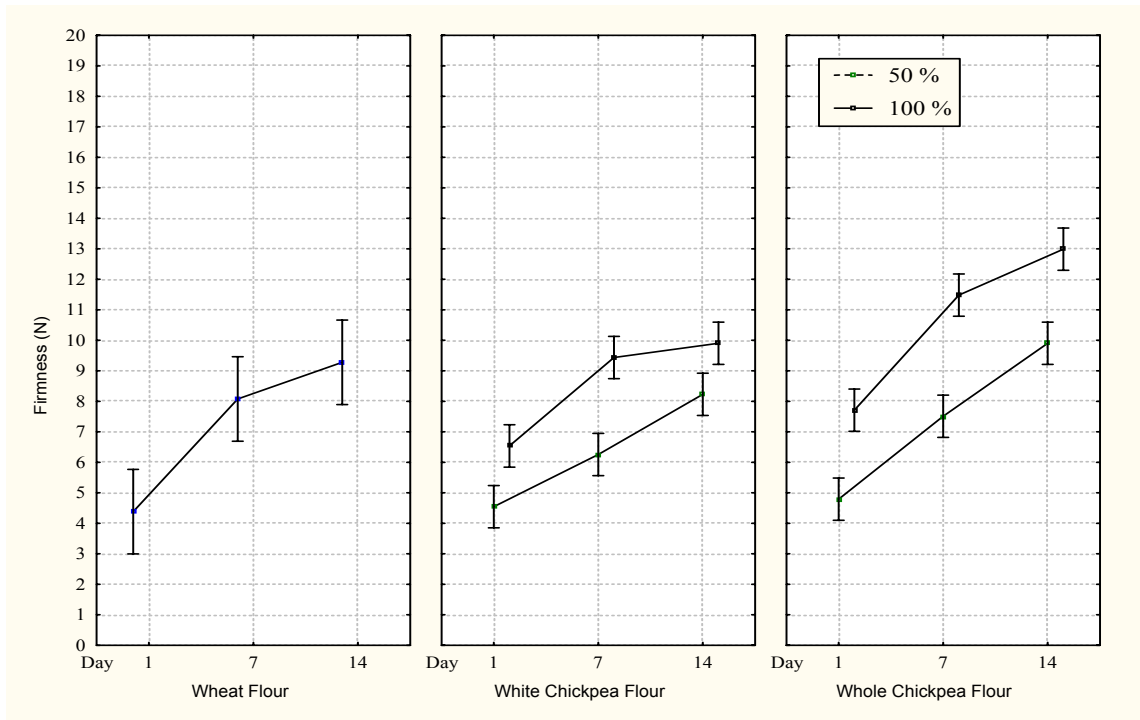
481 FIGURE CAPTIONS

482

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

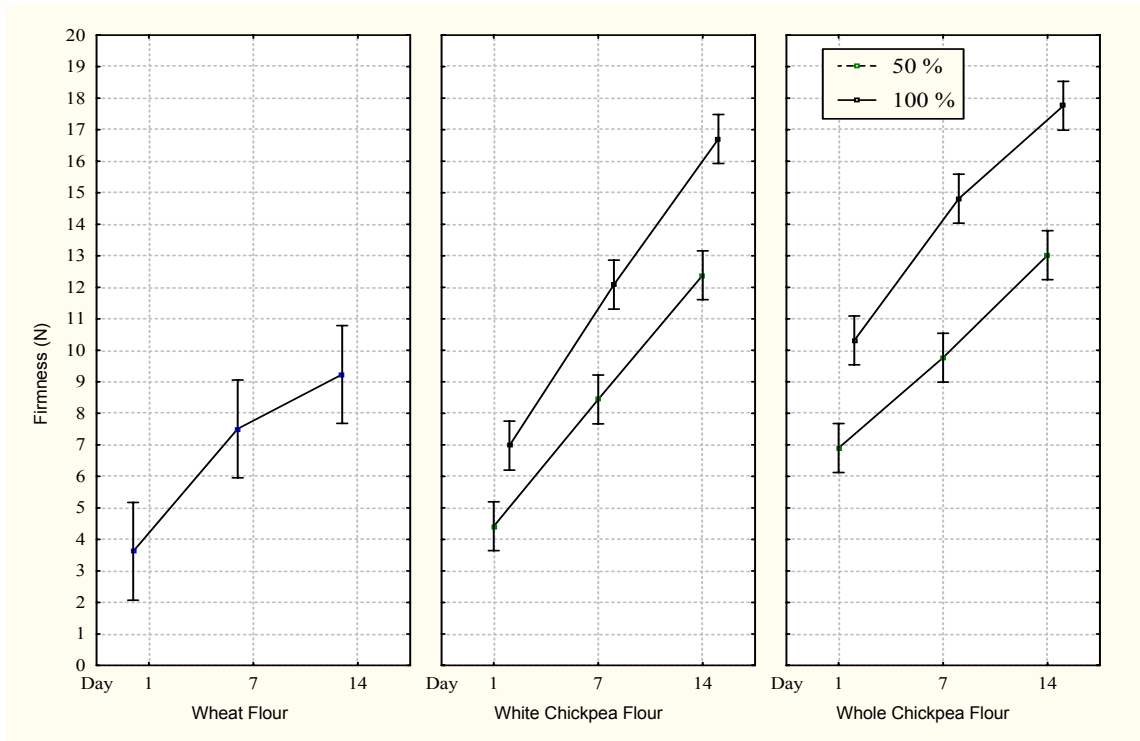
484 A: Cakes obtained from recipe A. B: Cakes obtained from recipe B.

485 Figure 1. A.



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488 B.



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Table 1: Cake formulations

Ingredients	A Cake		B Cake	
	(g)	%	(g)	%
Flour	700	27.5	490	26.5
Egg	350	13.8	688	37.3
Sugar	840	33	481	26
Powder Milk	42	1.6	50	2.7
Water	378	14.9	110	6
Oil	210	8.4	-	-
Emulsifier	-	-	28	1.5
Baking powder	21	0.8	-	-

Table 2: Proximate composition (g/100g) of wheat and chickpea flours

Kind of flour	Chickpea Cultivar	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Carbohydrates (by difference)
Wheat		10.81d	13.73a	1.40a	0.16a	0.78a	73.12c
Chickpea White	Andaluz	7.94b	24.65e	7.22f	1.36c	3.27b	55.56a
	Lechoso	8.02b	23.46cd	6.26d	1.14b	3.31b	57.81b
	Pedrosillano	8.47c	25.18f	4.62c	1.37c	3.46d	56.90ab
	Sinaloa	8.02b	23.09c	6.34de	1.41c	3.27b	57.87b
Chickpea Whole	Andaluz	7.98b	23.63d	6.87ef	2.72e	3.30b	55.50a
	Lechoso	7.44a	23.06c	6.76e	2.75ef	3.38c	56.61ab
	Pedrosillano	8.21bc	24.93ef	3.81b	2.78f	3.46d	56.81ab
	Sinaloa	7.26a	22.48b	6.58e	2.64d	3.44d	57.60b

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.

		Viscometric parameters on cooking and cooling (Rapid Visco Analyser)						
Kind of flour	Chickpea cultivar				Holding		Final	
		Peak viscosity	Peak Time	Pasting Temperature	strength	Breakdown	Total Setback	Viscosity
		cP	min	°C	cP	cP	cP	cP
Wheat		2621 e	6.3 b	50.1 a	1728 e	893 c	1485 c	3213 e
White chickpea	Andaluz	954 b	5.9 a	79.1 d	888 b	66 b	258 a	1146 b
	Lechoso	877 a	6.1 a	76.7 c	817 a	60 b	249 a	1066 a
	Pedrosillano	1001 c	6.4 b	79.8 d	963 d	38 a	247 a	1210 c
	Sinaloa	978 c	5.9 a	72.6 b	930 c	48 a	281 b	1211 c
Whole chickpea	Andaluz	936 b	6.9 c	79.1 d	887 b	49 a	279 b	1166 b
	Lechoso	1032 d	5.9 a	76.0 c	964 d	68 b	300 b	1264 d
	Pedrosillano	976 c	6.7 c	76.0 c	935 c	41 a	285 b	1220 c
	Sinaloa	987 c	6.7 c	75.9 c	919 c	68 b	275 b	1194 c

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

Table 4: Physical characteristics of batters and cakes

	Batter density		Volume (cm ³)		Weight (g)		Simetry		Volume Index	
	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake
Wheat flour / Chickpea flour										
100 / 0	1.05c	0.51a	397.50c	465.00c	183.50a	131.00a	39.90c	26.89c	171.10c	150.94b
50 /50	0.98b	0.58b	373.90b	455.31b	183.63a	130.81a	9.63b	20.72b	147.02b	145.71b
0/100	0.94a	0.60c	348.75a	434.69a	186.00b	131.06a	-3.76a	9.84a	125.22a	133.19a
Kind of flour										
White	0.95a	0.58a	360.16a	469.06b	185.50b	131.25a	0.82a	21.32b	137.77a	149.94b
Whole	0.96b	0.60b	362.50a	420.94a	184.13a	130.63a	5.05b	9.24a	134.47a	128.96a
Chickpea cultivar										
Andaluz	0.96b	0.62c	324.38a	418.75a	185.13cd	130.75a	-3.34a	14.30ab	127.40a	138.16a
Lechoso	0.96b	0.57a	398.13b	453.13bc	183.63a	130.88a	5.09b	16.57b	141.97b	137.54a
Pedrosillano	0.94a	0.60b	324.38a	448.13b	184.63bc	130.88a	-0.17a	17.01b	130.91a	142.94b
Sinaloa	0.98c	0.57a	388.75b	460.00c	185.88d	131.25a	10.15c	13.24a	144.19b	139.16a

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

Table 5: Crust and crumb colour of cakes

	Crust										Crumb											
	L*		a*		b*		Chroma		Hue angle		L*		a*		b*		Chroma		Hue angle			
	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake		
Wheat flour / Chickpea flour																						
100 / 0	50.13c	44.03a	11.73a	14.16b	12.53ab	23.74b	17.23ab	27.64b	46.11a	59.17b	66.79a	74.51b	1.41b	0.22a	15.81a	22.92a	15.87a	22.92a	84.89a	89.46b		
50 / 50	44.77b	46.17b	11.52a	13.36ab	14.84b	15.80a	18.91b	20.86a	51.46b	48.67a	64.80a	74.47b	0.69a	0.40a	21.60b	22.48a	21.62b	22.49a	88.16c	88.94b		
0 / 100	38.82a	45.05a	11.36a	13.18a	11.31a	15.08a	16.26a	20.10a	43.60a	48.36a	63.56a	72.80a	1.28b	1.15b	27.16c	26.68	27.20c	26.72b	87.23b	87.48a		
Kind of flour																						
White	40.46a	44.15a	10.95a	12.86a	12.53a	16.49a	17.01a	21.00a	46.91a	51.50b	62.77a	73.79a	0.81a	0.52a	23.79a	25.64b	23.83a	25.65b	88.06b	88.89b		
Whole	43.14b	47.08b	11.94b	13.67b	12.53a	14.39a	18.17a	19.97a	48.14a	45.53a	65.59b	73.48a	1.16b	1.03b	24.97b	23.52a	25.00b	23.55a	87.33a	87.53a		
Chickpea Cultivar																						
Andaluz	43.87b	44.46a	11.90b	13.24ab	10.06a	14.31ab	15.71a	19.52a	39.48a	47.14ab	65.87b	73.67ab	1.64c	0.87a	23.29a	24.20a	23.36a	24.22a	85.93a	87.99a		
Lechoso	42.53b	44.72a	11.62b	13.00a	17.02c	16.38ab	20.65c	21.14a	55.41b	50.18ab	63.20ab	72.88a	0.40a	0.68a	23.58a	23.41a	23.59a	23.44a	88.97c	88.33a		
Pedrosillano	36.60a	46.35b	10.23a	13.64b	11.81ab	17.11b	15.69a	21.93a	48.54b	51.02b	61.95a	74.05b	1.29b	0.77a	27.57b	26.93b	27.60b	26.95b	87.35b	88.46a		
Sinaloa	44.19b	46.92b	12.03b	13.19ab	13.40b	13.95a	18.30b	19.33a	46.67b	45.73a	65.72b	73.95b	0.61a	0.78a	23.08a	23.78a	23.10a	23.81a	88.54c	88.06a		

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

Table 6: Texture of fresh cakes

	Firmness (N)		Cohesiveness		Gumminess (N)		Chewiness (N)		Adhesiveness (N·s)		Springiness		Resilience	
	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake	A Cake	B Cake
Wheat flour /														
Chickpea flour														
100 / 0	4.38a	3.62a	0.68c	0.76c	2.98ab	2.74a	2.62b	2.45a	0.05b	0.09a	0.88c	0.89a	0.23c	0.27b
50 /50	4.67a	5.66b	0.56b	0.72b	2.59a	4.02b	2.06a	3.67a	0.11b	0.10a	0.80b	0.91a	0.17b	0.26b
0/100	7.12b	8.65c	0.47a	0.61a	3.35b	5.16c	2.36b	4.53b	0.41a	0.12a	0.71a	0.88a	0.13a	0.21a
Kind of flour														
White	5.54a	5.70a	0.51a	0.69b	2.76a	3.87a	2.07a	3.47a	0.25a	0.08a	0.75a	0.90a	0.15a	0.25b
Whole	6.25b	8.61b	0.52a	0.63a	3.18b	5.31b	2.36b	4.73b	0.27a	0.08a	0.75a	0.89a	0.16a	0.22a
Chickpea Cultivar														
Andaluz	6.15ab	7.15a	0.52a	0.67b	3.16b	4.61a	2.36bc	4.11a	0.43a	0.09a	0.75a	0.90a	0.15a	0.24a
Lechoso	5.22a	7.74a	0.52a	0.65a	2.62a	4.81a	1.96a	4.30a	0.17b	0.08a	0.75a	0.90a	0.16b	0.23a
Pedrosillano	6.97b	6.98a	0.51a	0.67b	3.44b	4.61a	2.53c	4.11a	0.27ab	0.07a	0.75a	0.89a	0.15a	0.24a
Sinaloa	5.24a	6.73a	0.52a	0.66ab	2.66a	4.33a	2.00ab	3.88a	0.18b	0.05a	0.75a	0.90a	0.16b	0.24a

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