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A fibre syrup for the sugar reduction in fruit filling for bakery application

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## A fibre syrup for the sugar reduction in fruit filling for bakery application

--Manuscript Draft--

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<b>Abstract:</b>	Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new fibre syrup based on corn ( Zea mais ) dextrin and seed coats of chickpeas (testa of Cicer arietinum seed) has been used to formulate reduced-sugar fruit fillings. Three reduced-sugar (by 30, 50 and 70%) recipes were developed starting from a standard formulation, in order to reach the "reduced in sugar" and "high in fibre" label claims. Physicochemical and sensory properties of the fruit fillings were assessed during 180 days of storage at two different temperatures (5°C and 25°C). Increased hardness, adhesiveness, consistency coefficient (K, flow behaviour), bake stability and colour differences have been observed in reformulated recipes with increasing fibre syrup content if compared to the control. Storage decreased bake stability and induced darkening of the product in all samples. 30% sugar-reduced filling were the most appreciated by consumers, and not distinguishable from the control. Overall results confirmed the syrup technological functionality when used to obtain a 30% sugar-reduction.
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<b>Response to Reviewers:</b>	

**Manuscript Number: IJGFS-D-22-00043**

**A fibre syrup for the sugar reduction in fruit filling for bakery application**

Response to the Reviewers second round

Reviewer #2: The Authors have made all suggested changes in the manuscript. There is one point that has to be addressed before publishing:

1. Fiber syrup color was not given numerically in CIE L\*a\*b\* coordinates, only described, although it was stated in Material and Methods section that it was measured.

The values of L\*, a\* and b\* coordinates have been reported in the "Results and Discussion" section.

1           **A fibre syrup for the sugar reduction in fruit filling for bakery application**

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Field Code Changed

28 **Abstract**

29 Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new  
30 fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of *Cicer arietinum*  
31 seed) has been used to formulate reduced-sugar fruit fillings. Three reduced-sugar (by 30, 50 and  
32 70%) recipes were developed starting from a standard formulation, in order to reach the “reduced in  
33 sugar” and “high in fibre” label claims. Physicochemical and sensory properties of the fruit fillings  
34 were assessed during 180 days of storage at two different temperatures (5°C and 25°C). Increased  
35 firmness, adhesiveness, consistency coefficient (K, flow behaviour), bake stability and colour  
36 differences have been observed in reformulated recipes with increasing fibre syrup content if  
37 compared to the control. Storage decreased bake stability and induced darkening of the product in all  
38 samples. 30% sugar-reduced filling were the most appreciated by consumers, and not distinguishable  
39 from the control. Overall results confirmed the syrup technological functionality when used to obtain  
40 a 30% sugar-reduction.

41  
42 **Keywords:** Fruit filling, sugar reduction, fibre syrup, dietary fibre.

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54 **1. Introduction**

55 In Europe, the estimated daily energy intake from sugar ranges between 15-21% in adult and between  
56 16%-26% in children of the total energy intake (Azaïs-Braesco et al., 2017). These values are not in  
57 line with the World Health Organization (WHO) guidelines (World Health Organization, 2015)  
58 which recommends a sugar intake < 10% of the total energy intake; high levels are related to health  
59 problems as obesity, diabetes, and dental caries (Schwingshackl et al., 2017; Te Morenga et al., 2012;  
60 Touger-Decker & van Loveren, 2003). Awareness campaigns from health institutions and  
61 governments are informing consumers on the adverse effect of a high sugar diet. As a result, the  
62 request of reduced-sugar products on the market is increasing (FIE Global, 2020).

63 To fulfil a high-quality demand, food technologists are called to a complex challenge namely the  
64 replacement of the several quality and technological roles of sugar in food. Among the strategies  
65 proposed to reduce sugar in foods (Hutchings et al., 2019), the use of sugar substitutes is considered  
66 the most appropriate and viable in an industrial context (Hutchings et al., 2019). Sugar sweetness can  
67 be nowadays easily replaced using non-caloric sweeteners. On the contrary, the replacement of the  
68 sugar bulking effect with a proper ingredient remains difficult, especially for high sugar content  
69 products as jam, jelly, fruit filling in which sugar can be up to 60% of the product.

70 Technological functionalities of sugar substitutes should also satisfy the more and more increasingly  
71 consumer request for clean label ingredients (Asioli et al., 2017; Osborn, 2015). Ingredients able to  
72 simultaneously satisfy both the technological requirement and the clean label standard are of great  
73 interest. Dietary fibres are easily recognisable and positively accepted by the consumers (Dhingra et  
74 al., 2012), and they have been used either as bulking agents or as nutritional improvers (Buttriss,  
75 2017; Shinwari & Rao, 2020).

76 In the frame of high sugar foods, bakery products which contain fruit-based filling are a growing sale  
77 sector (Cropotova et al., 2016). Fruit filling are mainly based on sugar, water, fruit puree/jam, flavour,  
78 and thickening agent (Wei et al., 2001). Despite the high sugar content of this food preparation, very  
79 few researchers worked on its sugar reduction; it has been reported the use of polydextrose (E1200)

80 that allowed to obtain similar structures between reduced- and full- sugar products (Agudelo et al.,  
81 2015a; Agudelo et al., 2015b).

82 A commercial fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of  
83 *Cicer arietinum* seed) was previously characterized and tested as sugar replacer in cookies and ripple  
84 sauces with encouraging results (Carcelli, Alberti et al., 2021; Carcelli, Suo et al., 2021).

85 In this work, same commercial fibre syrup was tested as buking agent ingredient to develop reduced-  
86 sugar fruit filling formulations. Fruit fillings with different reduced-sugar levels were developed and  
87 characterised for their physicochemical and sensory properties at 5°C and 25°C for a storage period  
88 of 180 days to replicate the typical storage condition of the product in the industrial context.

89

## 90 **2. Materials and methods**

### 91 **2.1 Materials**

92 A fibre syrup (MELTEC®) was obtained from HI-FOOD S.p.A. (Parma, Italy). It is a clean label  
93 ingredient, which does not impart sweetness, with a consistency like honey, a gold brownish colour.

94 Its dietary fibre content is  $\approx 66\%$  [(g fibre/100 g sample), High Molecular Weight Dietary Fiber and  
95 Low Molecular Weight Dietary Fiber (AOAC method 2009.01)], with a sugar content  $< 1.0\%$  (g

96 sugar/100 g sample), and a moisture content  $\approx 25\%$  (g water/100 g sample). The commercial fiber  
97 syrup was also characterized in terms of Brix degrees (portable refractometer HB 95, Lega Italy,

98 Ravenna, Italy), water activity at 25°C ( $a_w$ , Aqualab 4 TE, Decagon Devices Inc., Pullman, WA,  
99 USA), pH (potentiometer pH7+DHS Food, XS Instruments, Modena, Italy) and colour. Colour

100 analysis was performed using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan)  
101 equipped with a standard illuminant D65 and a 10° position of the standard observer. According to

102 CIE Lab system,  $L^*$  [0 (black) and 100 (white)],  $a^*$  ( $-a^*$ = greenness and  $+a^*$ =redness) and  $b^*$  ( $-b^*$ =  
103 blueness and  $+b^*$ = yellowness) parameters were measured. At least, three measurements were taken

104 for each analysis.

105 Other ingredients used in the fruit filling recipes were: low-methoxyl (LM) pectin Classic AB 902  
106 (Herbstreith&Fox KG, Werder, Germany), glucose syrup 60 dextrose equivalent DE “Glucoplus  
107 361” (Unigläd Ingredienti, Cuneo, Italy), tricalcium citrate (Giusto Faravelli, Milano, Italy),  
108 potassium sorbate (Giusto Faravelli, Milano, Italy), crystalline sucrose (British sugar, Peterborough,  
109 UK), apricot jam (Rogelfrut, Cuneo, Italy), citric acid (Brenntag, Milano, Italy), apricot flavour  
110 NATLQ10989 (Internation Taste Solution, Newbury, UK).

111

## 112 **2.2 Fruit filling preparation**

113 Full-sugar (FS) and reduced-sugar (RS) fruit filling recipes, based on industrial recipe, are shown in  
114 Table 1. RSs were formulated replacing all the glucose syrup and increasing level of crystalline  
115 sucrose with fibre syrup in a 1:1 weight ratio. The replacement of sugar was designed in order to  
116 achieve its reduction by 30% (RS30), 50% (RS50) and 70% (RS70). All fruit filling samples were  
117 produced using a bowl chopper (Polyfunctional QB 8-3, Roboqbo, Bologna, Italy). As a first  
118 production step, LM pectin was mixed with crystalline sucrose in a 1:5 ratio, the mixture obtained  
119 was then dissolved in half of the water present in the recipe and pre-heated at 80°C with a blender  
120 (Minipimer MQ5035, Braun, Germany) at 13500 rpm for 5 min. In parallel, the other ingredients as  
121 crystalline sucrose, tricalcium citrate, glucose syrup or fibre syrup (for RS recipes), apricot jam and  
122 the remaining water in which the potassium sorbate was previously dissolved, were added together  
123 in the bowl chopper. The ingredients were subsequently mixed at 500 rpm and subjected to a heat  
124 treatment at 75°C until reaching 73 °Brix. Subsequently, the pre-mix of LM pectin and crystalline  
125 sucrose was added to the bowl chopper continuing the mixing process at 500 rpm at 90°C under  
126 vacuum (1 bar) to concentrate the preparation at 72 °Brix. Afterwards, the citric acid dissolved in few  
127 drops of water and the liquid apricot flavouring were added checking the pH until reaching a value  
128 of 3.6. As a final step, the product was cooled under vacuum (1 bar) at 800 rpm until reaching 65°C.  
129 The filling was transferred into plastic container to be analysed after cooling to RT (t0) or stored at  
130 25°C or 5°C for analysis after 30, 60 and 180 days (t30, t60, t180). Filling formulations were

131 characterized during storage both at 5°C and 25°C to verify their quality in different and frequent  
132 storage and consuming conditions as raw materials or components in final products.

133 Two batches of product for each formulation were produced in two different days.

134

## 135 **2.3 Fruit filling characterisation**

### 136 **2.3.1 Nutritional profile**

137 Macronutrient profile of FS and RSs was calculated using the European Institute of Oncology  
138 database (IEO-DBA, 2020). Energy (kJ and kcal) was obtained multiplying all macronutrients for  
139 their energy factors cited in the EU Regulation on labelling of food products (Regulation (EU) No  
140 1169/2001).

### 141 **2.3.2 °Brix and pH**

142 °Brix of filling was measured using a refractometer HB 95 (Lega Italy, Ravenna, Italy) while pH with  
143 a potentiometer pH7+ DHS Food (XS Instruments, Modena, Italy). At least three measurements were  
144 taken at 25°C for each formulation for a total of six determinations.

### 145 **2.3.3 Water activity and moisture content**

146 Water activity was measured at 25 °C with an Aqualab 4 TE (Decagon Devices Inc. WA, USA).  
147 Moisture content (MC, g of water/100 g of sample) was measured by weight loss by drying in a  
148 forced-air oven (M120-TBR, MPM Instruments Srl, Milano, Italy) at 70 °C to constant weight.

149 At least three measurements were taken for each formulation for a total of six determinations at each  
150 storage time.

### 151 **2.3.4 Textural and rheological properties**

152 Texture properties were determined using TA.XT2 Texture Analyzer (Stable Micro Systems,  
153 Godalming, UK) equipped with a P/20 probe. A cylindrical container (58 X 70 mm) was completely  
154 filled with the product which it was subjected to a penetration test (50% strain at a rate of 0.8 mm/s).

155 Firmness (peak force, N) and adhesiveness (negative area, N mm) were determined. Five

156 measurements were taken for each batch for a total of ten determinations at each formulation and  
157 storage time.

158 A controlled stress rheometer (MCR 702 twin drive, Anton Paar, Graz, Austria) operating at 25°C  
159 with a 50 mm diameter plate-plate geometry and a gap of 1 mm was used to study the flow behaviour  
160 of fruit fillings. Before each analysis, the exposed surface of samples was protected with paraffin oil,  
161 besides the samples were allowed to rest for 3 minutes until axial force reached ~0 N. Flow curves  
162 were obtained increasing shear rates from 1 to 100 s<sup>-1</sup>. Power law equation was used to fit the  
163 experimental data, according to:

$$164 \quad \sigma = K\gamma^n$$

165 where  $\sigma$  is the shear stress (Pa),  $\gamma$  is the shear rate (s<sup>-1</sup>), K is the consistency coefficient (Pa·s<sup>n</sup>) and  $n$   
166 the non-Newtonian index (dimensionless).

167 Three measurements were performed for each batch for a total of six determinations for each  
168 formulation.

### 169 **2.3.5 Colour**

170 Colour was measured using the method reported by Carcelli and co-workers (Carcelli et al., 2020)  
171 using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan) equipped with a standard  
172 illuminant D65 and a 10° position of the standard observer. The results were expressed in accordance  
173 with the CIE Lab system;  $\Delta E$  was calculated using FS as a reference (Carcelli et al., 2020). Ten  
174 determinations were performed for each batch for a total of twenty determinations for each  
175 formulation.

### 176 **2.3.6 Syneresis and bake stability**

177 Syneresis was measured as described by Crobotova and co-workers (Crobotova et al., 2009). Samples  
178 of 5 g (F<sub>0</sub>) were transferred into a 50 ml falcon tube, sealed with plastic cap and centrifuged at 3000  
179 rpm for 20 min (centrifuge 5910R, Eppendorf, Milan, Italy). The weight of the supernatant fraction  
180 (F<sub>1</sub>) was measured and grade of syneresis was calculated as percentage (%) = (F<sub>1</sub>/F<sub>0</sub>)\*100. Three  
181 replicates for each batch for a total of six determinations for each formulation were carried out.

182 Bake stability was evaluated following Young and colleagues with slight modifications (Young et  
183 al., 2003). Fruit filling samples of 10 g were placed into a circular mould ( $\varnothing$  35 mm) on a 7x7 cm  
184 layer of short crust. On the circular sample obtained, 4 points have been marked on the external part  
185 to measure the pre- and post-baking (200° C, 10 min, 903.008.05, IKEA, Leida, Netherlands)  
186 diameter. Bake stability percentage (B.S.%) has been calculated according with:

$$187 \quad B.S.\% = 100 - \left[ \left( \frac{\varnothing_{pb} - \varnothing_{bb}}{\varnothing_{bb}} \right) * 100 \right]$$

188 where  $\varnothing_{pb}$  is diameter post baking while  $\varnothing_{bb}$  is diameter before baking.

189 Three measurements were performed for each batch changing the position of the short crust in the  
190 oven, for a total of six determinations for each formulation.

### 191 **2.3.7 Sensory analysis**

192 Sensory analysis of filling samples was realized using both an acceptability and a rapid profiling  
193 check-all-that-apply (CATA) test performed on samples immediately after production and after 60  
194 and 180 days (t0, t60, t180). The tests were performed to 50 untrained judges using the method  
195 reported by Carcelli and co-workers (Carcelli et al., 2020). For CATA test the attributes random  
196 reported in the questionnaire were: pleasant colour, unpleasant colour, opaque, orange, brown, shiny,  
197 acid, bitter, sweet, very sweet, slightly sweet, good taste, bad taste, mediocre taste, vegetal taste,  
198 apricot taste, good aftertaste, bad aftertaste, pleasant consistency, unpleasant consistency, melty, jelly,  
199 sticky, fluid, sandy. Data were collected as the times each attribute was selected for each sample.

200

### 201 **2.3 Statistical analysis**

202 Data were processed with a three-way ANOVA using three fixed factors: recipe (R), storage time  
203 (St) and storage temperature (ST). The evaluation of single factor and their interactions in the  
204 variability of each parameter was obtained with the partition of total variance of sum square (SS%).  
205 Significant differences ( $p \leq 0.05$ ) among different samples were assessed by one-way-analysis of  
206 variance (ANOVA) with a Duncan post-hoc test using an IBM SPSS statistical software (Version

207 24.0, SPSS Inc., Armonk, New York, USA). The contingency table of CATA dataset was obtained  
208 on the basis of samples and attributes. A correspondence analysis was performed to summarize the  
209 relationship between samples and attributes using Statistica software (Version.13.3, TIBCO Software  
210 Inc.).

211

212

### 213 3. Results and discussion

214 The high levels of sucrose and glucose syrup used by fruit fillings manufacturers strongly affect  
215 products overall quality. In this study, all the glucose syrup and increasing level of crystalline sucrose  
216 have been partially replaced with a commercial fibre syrup, in an attempt to develop products with  
217 reduced-sugar content. The physico-chemical characterization of the semi-solid fibre indicated that  
218 the fibre syrup had ~75 Brix, water activity ~0.88 and pH of ~6.4. As for fiber syrup colour, L\*  
219 resulted ~23, a\* ~0.34 and b\* ~3.34. The values of the coordinates a\* and b\* coordinates indicated  
220 the marked presence of redness and yellowness tones, thus confirming the brownish colour.

221 FS and RSs samples were prepared keeping constant pH and °Brix to replicate the industrial process.  
222 In particular, pH =  $3.6 \pm 0.1$  and °Brix =  $72 \pm 1$  were reached in all samples increasing the citric acid  
223 content and prolonging (where necessary) the cooking time, respectively. pH and °Brix were also  
224 monitored throughout the entire storage time (data not showed) indicating significant but slight  
225 changes and remaining in the desired range.

226

#### 227 3.1 Nutritional label information

228 Pillar of the study was the development of a filling formulation with an improved nutritional profile  
229 in terms of lower sugar and higher dietary fibre contents, if compared with a standard filling  
230 formulation. The nutritional labels of FS and RSs are reported in Table 2.

231 Energy decreased remarkably with the increase of the fibre syrup moving from 964 KJ/230 Kcal of  
232 FS to 831 KJ/198 Kcal, 724 KJ/173 Kcal and 620 KJ/148 Kcal of RS30, RS50 and RS70, respectively.

233 The energy decrease was associated to the decrease of the carbohydrates in favour of the dietary fibres  
234 which have a lower energy conversion factor as indicated in the EU Regulation on labelling of food  
235 products (Regulation (EU) No 1169/2001). Moreover, RSs presented a sugar content reduced by 30%  
236 (RS30, from 55.8 g/100 g to 39 g/100 g), 50% (RS50, from 55.8 g/100 g to 27.5 g/100 g) and 70%  
237 (RS70, from 55.8 g/100 g to 17 g/100) if compared with FS. A slight increase of protein content was  
238 observed for RS50 and RS70 (respectively 0.6 g/100 g and 0.9 g/100 g) due to the increase of the  
239 fibre syrup in the formulation which intrinsically has a low amount of residual protein content. The  
240 increase of the fibre syrup led to an increase in the fibre content in the recipe from 1 g/100 g of FS to  
241 15 g/100 g, 22.5 g/100 g and 30 g/100 g for RS30, RS50 and RS70, respectively. The decrease of  
242 sugar and the increase of fibre contents would allow to label all the RSs with the double nutritional  
243 claims “reduced in sugar” and “high in fibre” based on the EU regulation on nutritional and health  
244 claims (Regulation (EC) No 1924/2006).

245

### 246 **3.2 Physico-chemical characterization**

247 Product stability at rheological, chemical and microbiological level is strongly related to water  
248 activity ( $a_w$ ) and moisture content (MC). Both parameters for all samples during storage are reported  
249 in Table 3 while the statistical outputs can be found in Table 4.

250 MC was affected by recipe (R) increasing with the decrease of sugar in the recipe (from  $\approx 20\%$  in FS  
251 to  $\approx 23\%$  in RS70 at t0). Similarly,  $a_w$  was highly affected by R showing an increase with the decrease  
252 of sugar moving from  $\approx 0.80$  in FS to  $\approx 0.87$  in RS70. Similar trends were noticed at all storage  
253 temperatures and times. These results were related to the water content ( $\approx 25\%$  g water/100 g sample)  
254 of the fibre syrup used to partially replace sugar and/or to its different interaction with water than  
255 those developed by sugar. Indeed, sugar is highly hygroscopic and has higher capacity than fibre to  
256 bind water thanks to the higher amount of available free hydroxyl group compared to long chain  
257 polysaccharides. The increase of  $a_w$  and MC when sugar was replaced by vegetable fibres was  
258 previously reported in studies conducted on cakes, muffin and fruit jellies (Milner et al., 2020; Riedel

259 et al., 2015; Zahn et al., 2013). However, the increase of both parameters does not affect product  
260 microbiological stability because the product is acidic (pH ~3.6) and it is stabilised with a hot filling  
261 process. The use of fiber syrup as sugar substitute in non-acidic products should envisage acid  
262 regulation to ensure microbiological safety. MC was affected also by St which slightly fluctuated  
263 during storage probably due to a macroscopic water redistribution in the product. The storage  
264 temperature did not affect neither the moisture content and the water activity with only a slightly  
265 significant difference for FS and RS30 at t60.

266 Fruit fillings rheological properties were assessed using both empirical and fundamental techniques  
267 in order to verify agreement between the two analytical approaches providing useful information to  
268 those food industries able to implement only cheaper and easier rheological methods. Fillings'  
269 firmness and adhesiveness parameters (Figure 1) aimed to give some information related to the  
270 mouthfeel of the product which is an important quality characteristic of semi-solid foods as filling.  
271 These food materials indeed shall not be chewed and their texture features are directly perceived in  
272 the mouth by tongue receptors (Agudelo et al., 2015a). Three-way ANOVA (Table 4) highlighted  
273 that firmness and adhesiveness were primarily affected by R with a significant increase of both  
274 parameters with the sugar decrease in the recipes. The increase of firmness and adhesiveness was  
275 likely affected by the increase of the fibre syrup which bulking effect strongly impacted on the overall  
276 structure. This phenomenon is probably due to the interactions among the polysaccharide long chains  
277 present in the syrup which probably affected the macrostructure. At t30, t60 and t180, FS, RS30 and  
278 RS50 had comparable firmness and adhesiveness while RS70 was harder and more adhesive than all  
279 other samples.

280 Flow properties play a fundamental role in the quality characteristics of filling. Its fluidity and  
281 structure may modulate the flavour perception in the mouth and therefore influence consumer  
282 acceptability; moreover, pumping and baking phase at industrial level may be strongly affected by a  
283 change in system fluidity (Agudelo et al., 2015a; Razak et al., 2018; Wei et al., 2001). Flow curves

284 fitting allowed to calculate the non-Newtonian index ( $n$ , data not showed) and the consistency  
285 coefficient ( $K$ , Table 4, Figure 2).

286  $n$  index of fillings fell between 0.33-0.40, characterising the product as pseudo plastic fluid ( $n < 1$ ), as  
287 previously reported in fruit filling (Nalawade et al., 2017; Wei et al., 2001).  $n$  index was more affected  
288 by St with only slight significative variation during storage (Table 4).  $K$  was instead strongly  
289 influenced by R showing a significantly increase with the reduction of sugar. Higher  $K$  at all storage  
290 times and temperatures was observed for RS70 if compared to other samples. A good positive relation  
291 ( $r^2 = 0.96$ ) was found between firmness and  $K$ , probing accordance between empirical and  
292 fundamental rheological analysis. Overall, the fibre syrup used in this work increased firmness and  
293  $K$  when used to reduce sugar above 30%. On the contrary, polydextrose (E1200) was found to  
294 marginally affect the rheological properties of fruit filling when used to completely replace sugar  
295 (Agudelo et al., 2015b).

296 Consumer acceptability is strongly influenced by the colour which is one of the most important  
297 appearance factors, influencing also the flavour perception and the overall purchase decision (Pathare  
298 et al., 2013). The colour properties of fillings were therefore analysed (Table 5).

299 Colour was most affected by St (Table 4): a significant decrease of all colour parameters was noticed  
300 at both storage temperatures in all samples (more pronounced in FS). A decrease of  $L^*$ ,  $a^*$  and  $b^*$   
301 during storage was observed also in previous studies on apricot (Touati et al., 2014) and strawberry  
302 jam (Wicklund et al., 2005). The darkening of jam products during storage has been associated to the  
303 fruit anthocyanidins degradation. Anthocyanidins originate from anthocyanins degradation which  
304 occurs during thermal and mechanical production steps. Anthocyanidins are less stable than  
305 anthocyanins to light and oxygen and consequently more prone to browning reactions (Wicklund et  
306 al., 2005).

307 Colour was less affected by R (Table 4) where in fresh products a significative decrease of all  
308 parameters was noticed with the increase of the fibre syrup due to its intrinsic brownish colour. Colour  
309 changes as a function of St and R were also highlighted by the  $\Delta E$  values (Table 5). However, it is

310 important to remark that all the formulations studied did not contain any food colouring ingredients  
311 which could be included in the formulation in the industrial scale up in order to stabilise the product  
312 during storage and to counterbalance the presence of the fibre syrup.

313 Other fruit filling' quality features are the stability – preservation of the dimension at high temperature  
314 during baking (Agudelo et al., 2014; Young et al., 2003) and the absence of water syneresis as a  
315 migration of water from the fruit filling to the dough may lead to product inhomogeneity and  
316 stickiness (Cropotova et al., 2016). All filling formulations produced did not show water syneresis  
317 during storage. The absence of water syneresis also in the RSs in which MC and  $a_w$  were higher than  
318 in FS indicates that the fibre syrup had a positive technological role acting as stabilising ingredient.  
319 Bake stability results (Table 6) indicated its addiction by St showing a decrease during storage in all  
320 samples. Moreover, only at t0, formulations containing the fibre syrup showed a significantly increase  
321 of their bake stability index if compared with FS highlighting an improvement of this quality indicator  
322 in the fresh product.

323

### 324 **3.3 Sensory analysis**

325 All the fruit fillings were considered acceptable by the consumers (overall acceptability scores higher  
326 than 5 in all cases) with FS and RS30 considered the most preferred (score  $\approx 7$ ) (Figure 3). The lowest  
327 scores were attributed to RS70, in particular for consistency which was evaluated with a score  $< 5$   
328 indicating a worsening of the fruit filling structure probably due to its higher firmness, adhesiveness  
329 and K compared to the other formulations. No significative differences for sensory attributes were  
330 registered during storage. These findings are encouraging considering that the product sensory  
331 stability for long lasting shelf-life is a relevant quality feature. A better elucidation of the fillings'  
332 consumers perception was assessed using a CATA test. The two dimensions of the factor plane  
333 representing the CATA test conducted at t0 (Figure 4) explained  $\approx 93\%$  of the variance, with  
334 dimension 1 explaining  $\approx 80\%$  and dimension 2 explaining  $\approx 13\%$ . IDEAL fruit filling was described  
335 as fluid, pleasant consistency, melty, sweet, apricot taste, good aftertaste, good taste. Attributes as

336 “melty”, “sweet” and “fruity” were also found in the IDEAL filling in the study of (Agudelo et al.,  
337 2015b). FS and RS30 were described by similar attributes: pleasant colour, orange, shiny, very sweet.  
338 On the opposite, RS50 and RS70 were characterised by negative attributes as jelly, vegetal taste,  
339 mediocre taste, sticky and unpleasant colour (RS50), and opaque, acid, slightly sweet, bad aftertaste,  
340 unpleasant consistency, brown, bad taste, sandy and bitter (RS70). The negative attributes related to  
341 consistency for RS50 and RS70 highlighted that the use of the syrup in high amount led to a  
342 detrimental effect on product texture increasing the “jelly” perception which is the opposite of the  
343 fluid attribute applied for the IDEAL product. Consumers’ appreciation for the fruit filling fluid  
344 consistency was previously reported (Agudelo et al., 2015b). Overall, RS30 was the most appreciated  
345 reduced-sugar formulation based on both acceptability and CATA test, particularly for its texture  
346 properties. No remarkable differences on samples attributes were noticed during storage confirming  
347 the results of the acceptability test.

348

#### 349 **4. Conclusions**

350 “Sugar reduced” and “high in fibre” claims could be used to label reformulated fruit fillings by means  
351 of the use of a syrup based on chickpea and maize fibre as sugar replacer. The use of the syrup  
352 increased the  $a_w$ , MC as well as firmness, adhesiveness, K consistency coefficient and bake stability,  
353 while decreased the colour coordinates  $L^*$ ,  $a^*$ ,  $b^*$ . Storage time mainly affected the colour and the  
354 bake stability of all fruit fillings while the storage temperature presented a little or negligible effect  
355 on all studied parameters. When sugar was reduced by 30% the overall physicochemical and sensory  
356 properties of the reformulated fruit filling were found to be similar to the full-sugar counterpart.  
357 The use of the fibre syrup as clean label ingredient was found to be a valuable ingredient on a  
358 technological standpoint, allowing to improve the nutritional profile of the product and to partially  
359 replace the bulking agent role of sugar.

360

#### 361 **Acknowledgments**

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363

364 **Conflict of interests**

365 AC was involved in the research as Industrial PhD student. Universities involved in this research have  
366 not received any funding.

367

368 **Ethical guidelines statement**

369 All judges were previously informed about the scope of the research and of its non-commercial  
370 purpose, as well as their anonymous and voluntary participation. Moreover, judges were informed of  
371 the composition of the fruit fillings to exclude any allergic subject. Judges were also informed about  
372 the possible use of the data raised by the study for any scientific or informative communication.

373

374

375

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461 fibres for partial sucrose replacement in muffins. *LWT – Food Sci. Technol.*, 50(2), 695-701.

462

463 Table 1. Fruit filling recipes (% wt).

	FS	RS30	RS50	RS70	464
Sucrose	32	30.6	19.3	8.3	465
Glucose syrup	20	-	-	-	466
MELTEC®	-	21.4	32.7	43.7	467
Water	26.9	26.8	26.75	26.72	468
Apricot jam	20	20	20	20	469
Pectin	0.8	0.8	0.8	0.8	470
Citric acid	0.14	0.24	0.29	0.32	471
Tricalcium citrate	0.08	0.08	0.08	0.08	472
Potassium sorbate	0.05	0.05	0.05	0.05	473
Apricot flavour	0.03	0.03	0.03	0.03	

474 FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

475

476 Table 2. Nutritional composition based on Reg EU 1169/2011 of fruit fillings at different sucrose content (g/100g).

	<b>FS</b>	<b>RS30</b>	<b>RS50</b>	<b>RS70</b>	<b>477</b>
<b>Energy (kJ)</b>	964	831	724	620	478
<b>Energy (kcal)</b>	230	198	173	148	479
<b>Fat</b>	0	0	0	0	480
<b>-of which saturated</b>	0	0	0	0	481
<b>Carbohydrates</b>	57.0	41	30.5	20	482
<b>-of which sugars</b>	55.8	39	27.5	17	483
<b>Fibre</b>	1.0	15.0	22.5	30.0	484
<b>Protein</b>	0	0	0.6	0.9	485
<b>Salt</b>	0	0	0	0	

486 FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

487

488 Table 3. Moisture content (MC), water activity ( $a_w$ ) of fruit filling at different sugar content during storage (t0, t30, t60, t180) at  
 489 different temperatures (5°C, 25°C).

490

		Moisture content (MC) g H <sub>2</sub> O/ 100 g of sample			
		t0	t30	t60	t180
5 °C	FS	20.50 ±0.02 bB	22.50 ±0.01 bA	23.50 ±0.01 bA*	22.83 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.83 ±0.01 abA	24.17 ±0.01abA*	23.83 ±0.01 abA
	RS50	22.50±0.01 aB	24.50±0.02 aA	25.00±0.02 aA	24.67±0.02 aA
	RS70	23.00±0.01aB	23.67±0.01 abB	25.00±0.01 aA	23.67±0.01 abB
25° C	FS	20.50 ±0.02 bB	22.00 ±0.01 bA	22.83 ±0.01 bA*	22.33 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.33 ±0.01 aAB	23.67 ±0.01 bA*	23.83 ±0.01 aA
	RS50	22.50±0.01 aB	24.33 ±0.01 aA	24.67 ±0.01 aA	24.00 ±0.01 aA
	RS70	23.00±0.01aB	23.67±0.01 aB	24.67±0.01 aA	23.83±0.01 aAB

		Water activity ( $a_w$ )			
		t0	t30	t60	t 180
5 °C	FS	0.800 ±0.010 dA	0.801 ±0.014 dA	0.805 ±0.007 dA	0.794 ±0.004 dA
	RS30	0.836 ±0.007 cAB	0.836 ±0.009 cAB	0.842 ±0.004 cA	0.832 ±0.003 cB
	RS50	0.861 ±0.005 bA	0.858 ±0.005 bA	0.864 ±0.005 bA	0.857 ±0.008 bA
	RS70	0.874 ±0.003 aA	0.874 ±0.002 aA	0.876 ±0.003 aA	0.866 ±0.003 aB
25° C	FS	0.800 ±0.010 dA	0.798 ±0.009 dA	0.804 ±0.010 dA	0.784 ±0.004 dB
	RS30	0.836 ±0.007 cA	0.833 ±0.009 cA	0.839 ±0.003 cA	0.824 ±0.006 cB
	RS50	0.861 ±0.005 bA	0.857 ±0.004 bA	0.858 ±0.010 bA	0.846 ±0.010 bB
	RS70	0.874 ±0.003 aA	0.871 ±0.004 aA	0.875 ±0.003 aA	0.865 ±0.002 aB

491 All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among  
 492 sample ( $p \leq 0.05$ ), where the small letters due to the sugar content, capital letter due to the time of storage and \* due to temperature  
 493 of storage. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.  
 494

495 Table 4. Partition of the total variance of sum square (SS%) of each single factor (R: recipe, St: storage time; ST: storage  
 496 temperature) and their interactions for each parameter studied. In brackets the significance ( $p < 0.05$ ) of the influence of individual  
 497 factors and their interactions.

498  
 499  
 500

	R	St	ST	R*St	R*ST	St*ST	R*St*ST
$d_w$	96.6 (0.00)	2.5 (0.00)	0.3 (0.00)	0.1 (0.90)	0.1 (0.71)	0.2 (0.04)	0.2 (0.89)
MC	45.6 (0.00)	45.7 (0.00)	1.3 (0.07)	5.8 (0.12)	0.4 (0.81)	0.6 (0.71)	0.6 (0.99)
Firmness	48.5 (0.00)	39.4 (0.00)	2.4 (0.00)	5.0 (0.00)	0.3 (0.63)	4.0 (0.00)	0.4 (0.98)
Adhesiveness	63.4 (0.00)	21.5 (0.00)	5.0 (0.00)	4.7 (0.00)	0.3 (0.51)	4.8 (0.00)	0.3 (0.98)
$n$	17.8 (0.00)	37.8 (0.00)	11.1 (0.00)	15.5 (0.82)	0.0 (0.00)	15.6 (0.00)	2.2 (0.82)
K	78.7 (0.00)	9.7 (0.00)	4.9 (0.00)	1.0 (0.83)	0.3 (0.65)	4.5 (0.00)	0.9 (0.89)
L*	25.9 (0.00)	64.6 (0.00)	1.6 (0.00)	5.7 (0.00)	0.2 (0.63)	1.7 (0.00)	0.3 (0.40)
a*	29.5 (0.00)	57.5 (0.00)	0.2 (0.05)	2.5 (0.00)	0.4 (0.01)	8.8 (0.00)	1.1 (0.00)
b*	30.7 (0.00)	55.6 (0.00)	4.4 (0.00)	5.3 (0.00)	0.4 (0.00)	3.3 (0.00)	0.3 (0.00)
Bake stability	2.9 (0.00)	85.0 (0.00)	2.2 (0.00)	5.1 (0.00)	1.6 (0.00)	1.1 (0.00)	2.1 (0.00)

501

Table 5. Color parameters of fruit fillings at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

		t0		t30		t60		t180						
		5°C		25°C		5°C		25°C						
		$\Delta E$		$\Delta E$		$\Delta E$		$\Delta E$						
FS														
$L^*$		35.42 ± 1.70 aA		33.16 ± 1.27aB		33.71 ± 1.89aB		30.71 ± 1.35aC		30.58 ± 1.39aC		30.51 ± 1.16aC		28.48 ± 1.01abD
$a^*$		10.71 ± 1.28aA	-	8.44 ± 1.28aB	-	9.19 ± 1.91aB	-	6.53 ± 1.24aC	-	5.70 ± 1.53aC	-	6.36 ± 1.14aC*	-	4.87 ± 0.92aC*
$b^*$		15.00 ± 2.40aA		11.80 ± 1.83aB		13.35 ± 2.72aB		8.50 ± 1.39aC		8.03 ± 1.85aC		8.27 ± 1.56aC		5.42 ± 0.99aD
$\Delta E$		-		4.5		2.8		9.1		9.8		9.4		13.2
RS30														
$L^*$		32.40 ± 1.50bA		30.98 ± 0.42bB		30.86 ± 0.75bB		29.57 ± 0.78bC		29.43 ± 1.10bC		29.52 ± 1.24bC		27.89 ± 1.05abD
$a^*$		9.18 ± 1.78bA	5.3	7.66 ± 0.80bB	3.9	8.51 ± 1.59bA	5.2	5.25 ± 1.32bC	2.18	5.16 ± 1.94abB	2.4	6.88 ± 1.25aD*	1.25	4.10 ± 1.05aB*
$b^*$		10.85 ± 2.02bA		8.71 ± 0.76bB		9.03 ± 1.34bB		7.16 ± 0.95bC		6.03 ± 1.50bC		7.70 ± 1.47aC		4.10 ± 0.79bD
$\Delta E$		-		3.0		2.5		6.1		6.9		4.8		9.6
RS50														
$L^*$		31.76 ± 1.01bA		29.70 ± 0.54cB		29.71 ± 0.52cB		28.97 ± 0.4cC*		28.28 ± 0.37cC*		28.28 ± 0.85cD		27.74 ± 1.14bC
$a^*$		8.56 ± 1.36bA	6.8	6.07 ± 0.90cB*	6.3	6.76 ± 0.71cB*	7.8	4.10 ± 0.62cC	4.0	4.35 ± 1.15bcC	3.8	4.78 ± 0.95bcC*	3.77	4.15 ± 1.59aC*
$b^*$		9.65 ± 1.26bA		7.12 ± 0.91cB		7.10 ± 0.58cB		5.82 ± 0.64cC*		5.34 ± 0.48cC*		5.66 ± 1.04bC		4.11 ± 1.01bD
$\Delta E$		-		4.1		3.7		6.5		7.0		6.5		8.1
RS70														
$L^*$		30.75 ± 1.12cA		30.26 ± 1.0cA*		29.53 ± 0.4cB*		28.52 ± 0.3cB*		28.17 ± 0.40cC*		28.42 ± 0.92cB		28.90 ± 2.2aBC
$a^*$		6.91 ± 1.00cA	9.2	5.51 ± 0.90cB	6.1	5.92 ± 0.57cB	8.5	3.74 ± 1.12cC	4.7	3.45 ± 0.39cC	4.8	4.13 ± 0.75bcC*	4.38	2.50 ± 0.88bD*
$b^*$		8.00 ± 0.69cA		7.25 ± 1.26cB		6.68 ± 0.53cB		5.42 ± 0.73cC*		4.60 ± 0.41cC		5.13 ± 0.78bC		3.06 ± 0.81cD
$\Delta E$		-		1.7		2.0		4.7		5.5		4.6		6.9

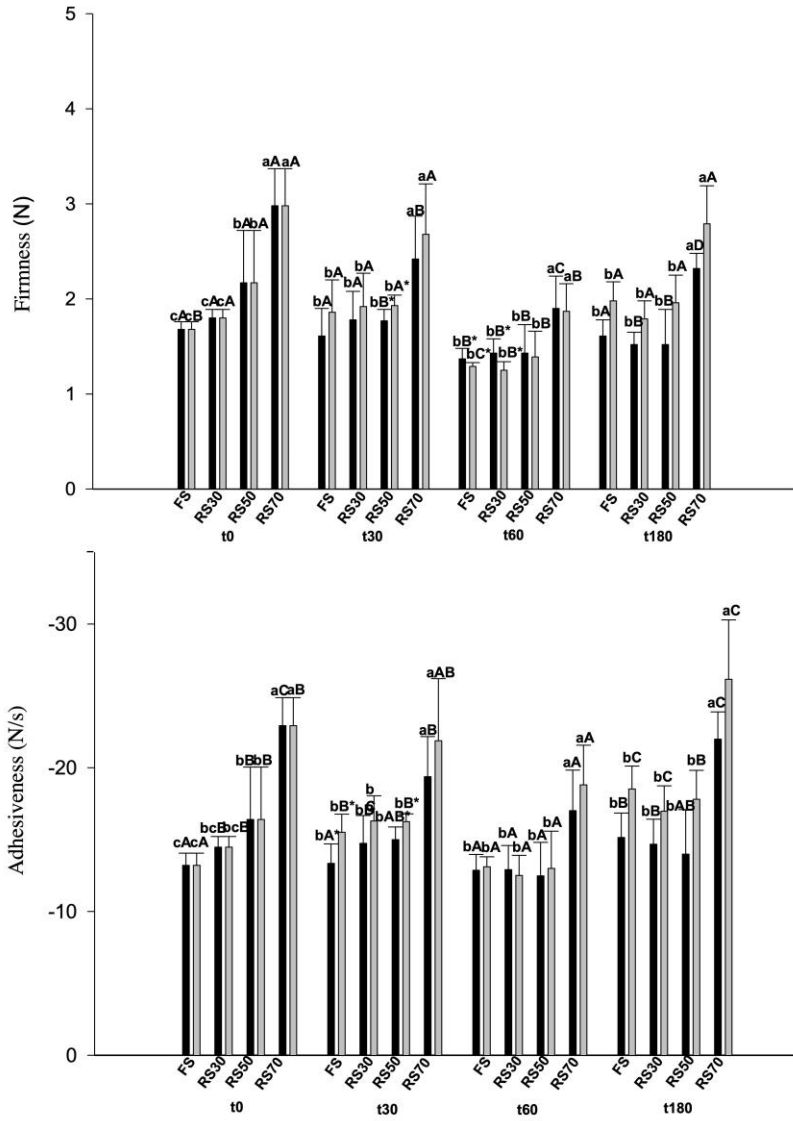
All the data are expressed as mean ± standard deviations; different letters close to number indicate significant difference among samples ( $p \leq 0.05$ ), where the small letters due to the sugar content, capital letter due to the time of storage and \* due to temperature of storage. Vertically are reported  $\Delta E$  associated to the reformulation while horizontally  $\Delta E$  associated to the storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

502 Table 6. Bake stability of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperature (5°C,  
 503 25°C).

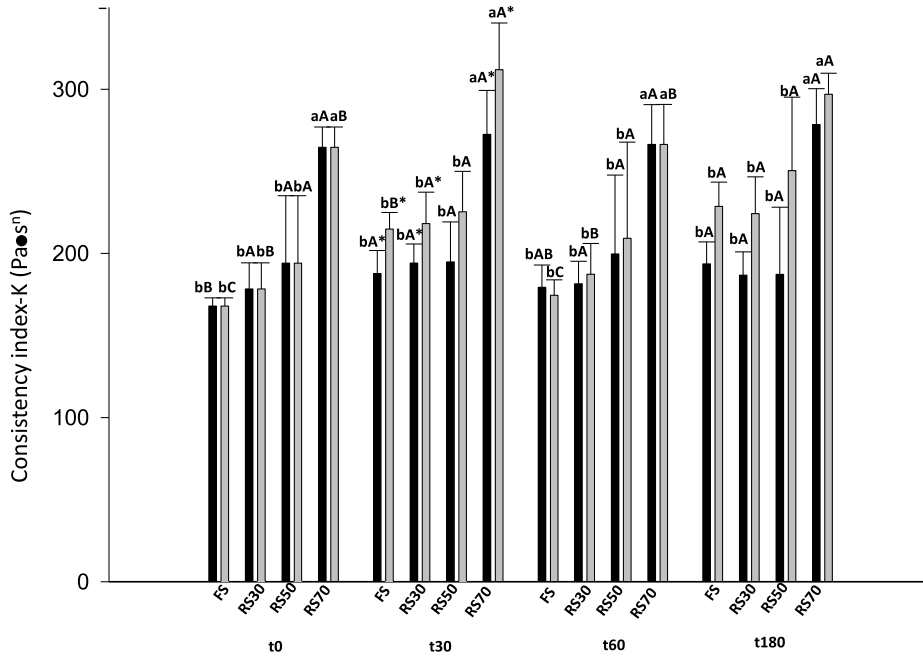
		Bake stability (%)			
		t0	t30	t60	t180
5 °C	FS	77.75 ± 0.10 bA	69.75 ± 0.12 aB	69.13 ± 0.05 aB	62.38 ± 0.09 aC
	RS30	81.58 ± 0.05 aA	75.54 ± 0.13 aB	68.63 ± 0.07 aC	60.71 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	74.04 ± 0.10 aB	71.29 ± 0.10 aB*	58.46 ± 0.08 aC
	RS70	85.04 ± 0.05 aA	76.04 ± 0.10 aB	69.67 ± 0.09 aC	60.21 ± 0.07 aD
25° C	FS	77.75 ± 0.10 bA	74.67 ± 0.11 aA	69.08 ± 0.08 aB	65.33 ± 0.10 aB
	RS30	81.58 ± 0.05 abA	76.71 ± 0.07 aB	69.13 ± 0.08 aC	63.46 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	76.25 ± 0.04 aB	65.29 ± 0.05 aB	56.54 ± 0.08 aB
	RS70	85.04 ± 0.05 aA	72.04 ± 0.08 aB	65.17 ± 0.08 aC	62.13 ± 0.09 aC

504 All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample  
 505 (p ≤ 0.05), where the small letters due to the sugar content, capital letter due to storage time and \* due to storage temperature. FS: full  
 506 sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

507 Figure 1. Firmness and adhesiveness of fruit fillings at variable sucrose content during storage at different temperatures (black:  
 508 5°C, grey: 25°C). Different letters close to the bar indicated significant difference among sample ( $p \leq 0.05$ ) where the small  
 509 letters were due to the sugar content while capital letter to storage time, and \* symbol represented the difference due to storage  
 510 temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

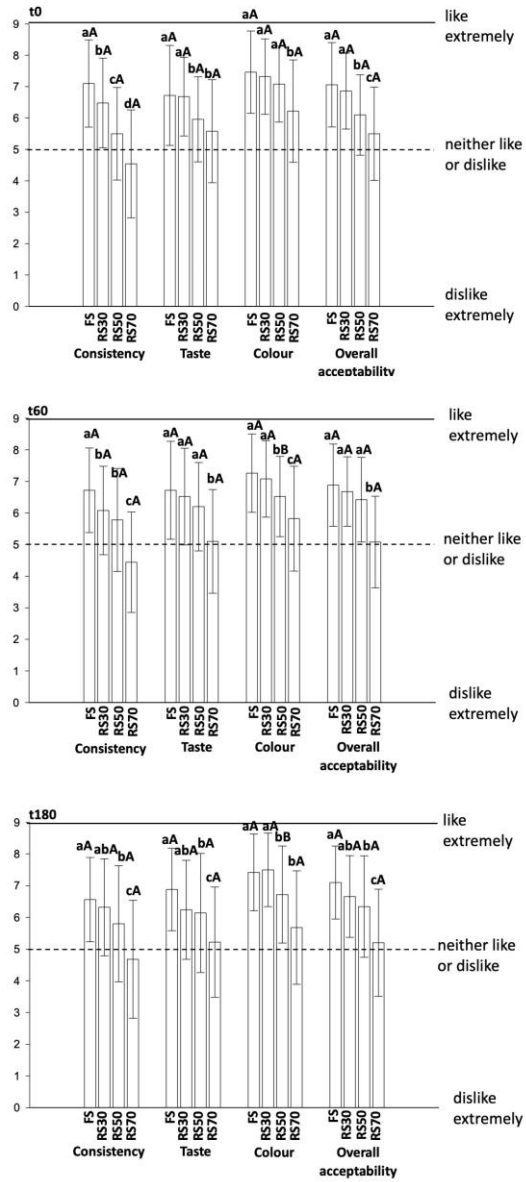


513 Figure 2. Consistency index of fruit fillings at variable sucrose content during storage at different temperatures (black: 5°C, grey:  
 514 25°C). Different letters close to the bar indicate significative difference among sample ( $P \leq 0.05$ ) where the small letters due to  
 515 the sugar content, capital letter due to storage time and \* symbol due to storage temperature. FS: full sugar; RS30: 30% sugar  
 516 reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

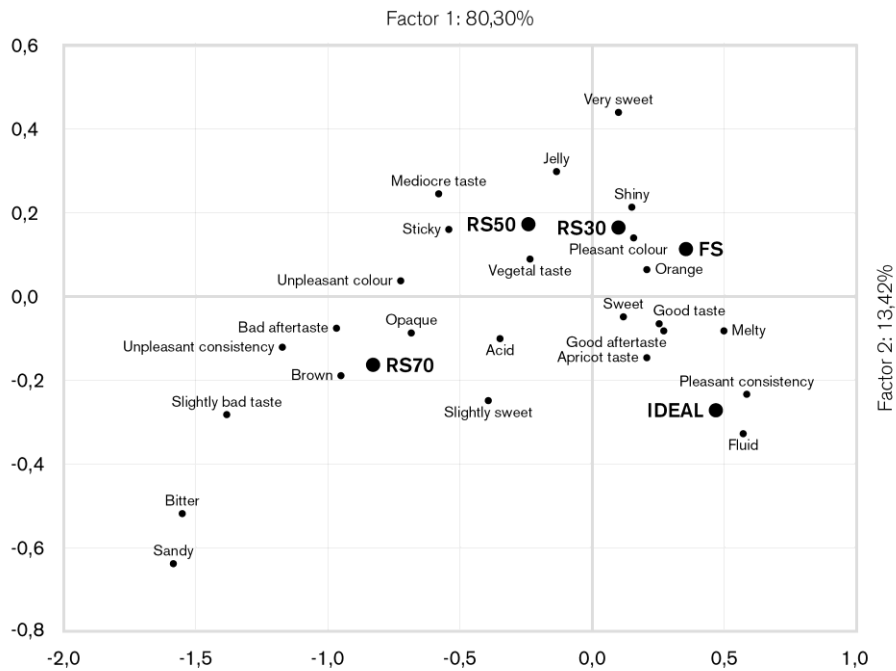


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518

519 Figure 3. Sensory scores for consistency, taste, colour and overall acceptability of fruit filling at variable sucrose content.  
 520 Different letters close to the bar indicate significant difference among sample ( $p \leq 0.05$ ) where the small letters due to the sugar  
 521 content, capital letter due to storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70%  
 522 sugar reduction.



524 Figure 4. Correspondence analysis of the CATA test data of fruit filling formulated with  
 525 different sucrose content. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar  
 526 reduction; RS70: 70% sugar reduction.  
 527



528

1                    **A fibre syrup for the sugar reduction in fruit filling for bakery application**

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28 **Abstract**

29 Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new  
30 fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of *Cicer arietinum*  
31 seed) has been used to formulate reduced-sugar fruit fillings. Three reduced-sugar (by 30, 50 and  
32 70%) recipes were developed starting from a standard formulation, in order to reach the “reduced in  
33 sugar” and “high in fibre” label claims. Physicochemical and sensory properties of the fruit fillings  
34 were assessed during 180 days of storage at two different temperatures (5°C and 25°C). Increased  
35 firmness, adhesiveness, consistency coefficient (K, flow behaviour), bake stability and colour  
36 differences have been observed in reformulated recipes with increasing fibre syrup content if  
37 compared to the control. Storage decreased bake stability and induced darkening of the product in all  
38 samples. 30% sugar-reduced filling were the most appreciated by consumers, and not distinguishable  
39 from the control. Overall results confirmed the syrup technological functionality when used to obtain  
40 a 30% sugar-reduction.

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42 **Keywords:** Fruit filling, sugar reduction, fibre syrup, dietary fibre.

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54 **1. Introduction**

55 In Europe, the estimated daily energy intake from sugar ranges between 15-21% in adult and between  
56 16%-26% in children of the total energy intake (Azaïs-Braesco et al., 2017). These values are not in  
57 line with the World Health Organization (WHO) guidelines (World Health Organization, 2015)  
58 which recommends a sugar intake < 10% of the total energy intake; high levels are related to health  
59 problems as obesity, diabetes, and dental caries (Schwingshackl et al., 2017; Te Morenga et al., 2012;  
60 Touger-Decker & van Loveren, 2003). Awareness campaigns from health institutions and  
61 governments are informing consumers on the adverse effect of a high sugar diet. As a result, the  
62 request of reduced-sugar products on the market is increasing (FIE Global, 2020).

63 To fulfil a high-quality demand, food technologists are called to a complex challenge namely the  
64 replacement of the several quality and technological roles of sugar in food. Among the strategies  
65 proposed to reduce sugar in foods (Hutchings et al., 2019), the use of sugar substitutes is considered  
66 the most appropriate and viable in an industrial context (Hutchings et al., 2019). Sugar sweetness can  
67 be nowadays easily replaced using non-caloric sweeteners. On the contrary, the replacement of the  
68 sugar bulking effect with a proper ingredient remains difficult, especially for high sugar content  
69 products as jam, jelly, fruit filling in which sugar can be up to 60% of the product.

70 Technological functionalities of sugar substitutes should also satisfy the more and more increasingly  
71 consumer request for clean label ingredients (Asioli et al., 2017; Osborn, 2015). Ingredients able to  
72 simultaneously satisfy both the technological requirement and the clean label standard are of great  
73 interest. Dietary fibres are easily recognisable and positively accepted by the consumers (Dhingra et  
74 al., 2012), and they have been used either as bulking agents or as nutritional improvers (Buttriss,  
75 2017; Shinwari & Rao, 2020).

76 In the frame of high sugar foods, bakery products which contain fruit-based filling are a growing sale  
77 sector (Cropotova et al., 2016). Fruit filling are mainly based on sugar, water, fruit puree/jam, flavour,  
78 and thickening agent (Wei et al., 2001). Despite the high sugar content of this food preparation, very  
79 few researchers worked on its sugar reduction; it has been reported the use of polydextrose (E1200)

80 that allowed to obtain similar structures between reduced- and full- sugar products (Agudelo et al.,  
81 2015a; Agudelo et al., 2015b).

82 A commercial fibre syrup based on corn (*Zea mays*) dextrin and seed coats of chickpeas (testa of  
83 *Cicer arietinum* seed) was previously characterized and tested as sugar replacer in cookies and ripple  
84 sauces with encouraging results (Carcelli, Alberti et al., 2021; Carcelli, Suo et al., 2021).

85 In this work, same commercial fibre syrup was tested as buking agent ingredient to develop reduced-  
86 sugar fruit filling formulations. Fruit fillings with different reduced-sugar levels were developed and  
87 characterised for their physicochemical and sensory properties at 5°C and 25°C for a storage period  
88 of 180 days to replicate the typical storage condition of the product in the industrial context.

89

## 90 **2. Materials and methods**

### 91 **2.1 Materials**

92 A fibre syrup (MELTEC<sup>®</sup>) was obtained from HI-FOOD S.p.A. (Parma, Italy). It is a clean label  
93 ingredient, which does not impart sweetness, with a consistency like honey, a gold brownish colour.  
94 Its dietary fibre content is  $\approx 66\%$  [(g fibre/100 g sample), High Molecular Weight Dietary Fiber and  
95 Low Molecular Weight Dietary Fiber (AOAC method 2009.01)], with a sugar content  $< 1.0\%$  (g  
96 sugar/100 g sample), and a moisture content  $\approx 25\%$  (g water/100 g sample). The commercial fiber  
97 syrup was also characterized in terms of Brix degrees (portable refractometer HB 95, Lega Italy,  
98 Ravenna, Italy), water activity at 25°C ( $a_w$ , Aqualab 4 TE, Decagon Devices Inc., Pullman, WA,  
99 USA), pH (potentiometer pH7+DHS Food, XS Instruments, Modena, Italy) and colour. Colour  
100 analysis was performed using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan)  
101 equipped with a standard illuminant D65 and a 10° position of the standard observer. According to  
102 CIE Lab system,  $L^*$  [0 (black) and 100 (white)],  $a^*$  ( $-a^*$ = greenness and  $+a^*$ =redness) and  $b^*$  ( $-b^*$ =  
103 blueness and  $+b^*$ = yellowness) parameters were measured. At least, three measurements were taken  
104 for each analysis.

105 Other ingredients used in the fruit filling recipes were: low-methoxyl (LM) pectin Classic AB 902  
106 (Herbstreith&Fox KG, Werder, Germany), glucose syrup 60 dextrose equivalent DE “Glucoplus  
107 361” (Uniglad Ingredienti, Cuneo, Italy), tricalcium citrate (Giusto Faravelli, Milano, Italy),  
108 potassium sorbate (Giusto Faravelli, Milano, Italy), crystalline sucrose (British sugar, Peterborough,  
109 UK), apricot jam (Rogelfrut, Cuneo, Italy), citric acid (Brenntag, Milano, Italy), apricot flavour  
110 NATLQ10989 (Internation Taste Solution, Newbury, UK).

111

## 112 **2.2 Fruit filling preparation**

113 Full-sugar (FS) and reduced-sugar (RS) fruit filling recipes, based on industrial recipe, are shown in  
114 Table 1. RSs were formulated replacing all the glucose syrup and increasing level of crystalline  
115 sucrose with fibre syrup in a 1:1 weight ratio. The replacement of sugar was designed in order to  
116 achieve its reduction by 30% (RS30), 50% (RS50) and 70% (RS70). All fruit filling samples were  
117 produced using a bowl chopper (Polyfunctional QB 8-3, Roboqbo, Bologna, Italy). As a first  
118 production step, LM pectin was mixed with crystalline sucrose in a 1:5 ratio, the mixture obtained  
119 was then dissolved in half of the water present in the recipe and pre-heated at 80°C with a blender  
120 (Minipimer MQ5035, Braun, Germany) at 13500 rpm for 5 min. In parallel, the other ingredients as  
121 crystalline sucrose, tricalcium citrate, glucose syrup or fibre syrup (for RS recipes), apricot jam and  
122 the remaining water in which the potassium sorbate was previously dissolved, were added together  
123 in the bowl chopper. The ingredients were subsequently mixed at 500 rpm and subjected to a heat  
124 treatment at 75°C until reaching 73 °Brix. Subsequently, the pre-mix of LM pectin and crystalline  
125 sucrose was added to the bowl chopper continuing the mixing process at 500 rpm at 90°C under  
126 vacuum (1 bar) to concentrate the preparation at 72 °Brix. Afterwards, the citric acid dissolved in few  
127 drops of water and the liquid apricot flavouring were added checking the pH until reaching a value  
128 of 3.6. As a final step, the product was cooled under vacuum (1 bar) at 800 rpm until reaching 65°C.  
129 The filling was transferred into plastic container to be analysed after cooling to RT (t0) or stored at  
130 25°C or 5°C for analysis after 30, 60 and 180 days (t30, t60, t180). Filling formulations were

131 characterized during storage both at 5°C and 25°C to verify their quality in different and frequent  
132 storage and consuming conditions as raw materials or components in final products.

133 Two batches of product for each formulation were produced in two different days.

134

## 135 **2.3 Fruit filling characterisation**

### 136 **2.3.1 Nutritional profile**

137 Macronutrient profile of FS and RSs was calculated using the European Institute of Oncology  
138 database (IEO-DBA, 2020). Energy (kJ and kcal) was obtained multiplying all macronutrients for  
139 their energy factors cited in the EU Regulation on labelling of food products (Regulation (EU) No  
140 1169/2001).

### 141 **2.3.2 °Brix and pH**

142 °Brix of filling was measured using a refractometer HB 95 (Lega Italy, Ravenna, Italy) while pH with  
143 a potentiometer pH7+ DHS Food (XS Instruments, Modena, Italy). At least three measurements were  
144 taken at 25°C for each formulation for a total of six determinations.

### 145 **2.3.3 Water activity and moisture content**

146 Water activity was measured at 25 °C with an Aqualab 4 TE (Decagon Devices Inc. WA, USA).  
147 Moisture content (MC, g of water/100 g of sample) was measured by weight loss by drying in a  
148 forced-air oven (M120-TBR, MPM Instruments Srl, Milano, Italy) at 70 °C to constant weight.  
149 At least three measurements were taken for each formulation for a total of six determinations at each  
150 storage time.

### 151 **2.3.4 Textural and rheological properties**

152 Texture properties were determined using TA.XT2 Texture Analyzer (Stable Micro Systems,  
153 Godalming, UK) equipped with a P/20 probe. A cylindrical container (58 X 70 mm) was completely  
154 filled with the product which it was subjected to a penetration test (50% strain at a rate of 0.8 mm/s).  
155 Firmness (peak force, N) and adhesiveness (negative area, N mm) were determined. Five

156 measurements were taken for each batch for a total of ten determinations at each formulation and  
157 storage time.

158 A controlled stress rheometer (MCR 702 twin drive, Anton Paar, Graz, Austria) operating at 25°C  
159 with a 50 mm diameter plate-plate geometry and a gap of 1 mm was used to study the flow behaviour  
160 of fruit fillings. Before each analysis, the exposed surface of samples was protected with paraffin oil,  
161 besides the samples were allowed to rest for 3 minutes until axial force reached ~0 N. Flow curves  
162 were obtained increasing shear rates from 1 to 100 s<sup>-1</sup>. Power law equation was used to fit the  
163 experimental data, according to:

$$164 \quad \sigma = K\gamma^n$$

165 where  $\sigma$  is the shear stress (Pa),  $\gamma$  is the shear rate (s<sup>-1</sup>), K is the consistency coefficient (Pa\*s<sup>n</sup>) and  $n$   
166 the non-Newtonian index (dimensionless).

167 Three measurements were performed for each batch for a total of six determinations for each  
168 formulation.

### 169 **2.3.5 Colour**

170 Colour was measured using the method reported by Carcelli and co-workers (Carcelli et al., 2020)  
171 using a Minolta Colorimeter (CM 2600d, Minolta Co., Osaka, Japan) equipped with a standard  
172 illuminant D65 and a 10° position of the standard observer. The results were expressed in accordance  
173 with the CIE Lab system;  $\Delta E$  was calculated using FS as a reference (Carcelli et al., 2020). Ten  
174 determinations were performed for each batch for a total of twenty determinations for each  
175 formulation.

### 176 **2.3.6 Syneresis and bake stability**

177 Syneresis was measured as described by Cropotova and co-workers (Cropotova et al., 2009). Samples  
178 of 5 g (F<sub>0</sub>) were transferred into a 50 ml falcon tube, sealed with plastic cap and centrifuged at 3000  
179 rpm for 20 min (centrifuge 5910R, Eppendorf, Milan, Italy). The weight of the supernatant fraction  
180 (F<sub>1</sub>) was measured and grade of syneresis was calculated as percentage (%) = (F<sub>1</sub>/F<sub>0</sub>)\*100. Three  
181 replicates for each batch for a total of six determinations for each formulation were carried out.

182 Bake stability was evaluated following Young and colleagues with slight modifications (Young et  
183 al., 2003). Fruit filling samples of 10 g were placed into a circular mould ( $\varnothing$  35 mm) on a 7x7 cm  
184 layer of short crust. On the circular sample obtained, 4 points have been marked on the external part  
185 to measure the pre- and post-baking (200° C, 10 min, 903.008.05, IKEA, Leida, Netherlands)  
186 diameter. Bake stability percentage (B.S.%) has been calculated according with:

$$187 \quad B.S.\% = 100 - \left[ \left( \frac{\varnothing pb - \varnothing bb}{\varnothing bb} \right) * 100 \right]$$

188 where  $\varnothing pb$  is diameter post baking while  $\varnothing bb$  is diameter before baking.

189 Three measurements were performed for each batch changing the position of the short crust in the  
190 oven, for a total of six determinations for each formulation.

### 191 **2.3.7 Sensory analysis**

192 Sensory analysis of filling samples was realized using both an acceptability and a rapid profiling  
193 check-all-that-apply (CATA) test performed on samples immediately after production and after 60  
194 and 180 days (t0, t60, t180). The tests were performed to 50 untrained judges using the method  
195 reported by Carcelli and co-workers (Carcelli et al., 2020). For CATA test the attributes random  
196 reported in the questionnaire were: pleasant colour, unpleasant colour, opaque, orange, brown, shiny,  
197 acid, bitter, sweet, very sweet, slightly sweet, good taste, bad taste, mediocre taste, vegetal taste,  
198 apricot taste, good aftertaste, bad aftertaste, pleasant consistency, unpleasant consistency, melty, jelly,  
199 sticky, fluid, sandy. Data were collected as the times each attribute was selected for each sample.

200

### 201 **2.3 Statistical analysis**

202 Data were processed with a three-way ANOVA using three fixed factors: recipe (R), storage time  
203 (St) and storage temperature (ST). The evaluation of single factor and their interactions in the  
204 variability of each parameter was obtained with the partition of total variance of sum square (SS%).  
205 Significant differences ( $p \leq 0.05$ ) among different samples were assessed by one-way-analysis of  
206 variance (ANOVA) with a Duncan post-hoc test using an IBM SPSS statistical software (Version

207 24.0, SPSS Inc., Armonk, New York, USA). The contingency table of CATA dataset was obtained  
208 on the basis of samples and attributes. A correspondence analysis was performed to summarize the  
209 relationship between samples and attributes using Statistica software (Version.13.3, TIBCO Software  
210 Inc.).

211

212

### 213 **3. Results and discussion**

214 The high levels of sucrose and glucose syrup used by fruit fillings manufacturers strongly affect  
215 products overall quality. In this study, all the glucose syrup and increasing level of crystalline sucrose  
216 have been partially replaced with a commercial fibre syrup, in an attempt to develop products with  
217 reduced-sugar content. The physico-chemical characterization of the semi-solid fibre indicated that  
218 the fibre syrup had ~75 Brix, water activity ~0.88 and pH of ~6.4. As for fiber syrup colour, L\*  
219 resulted ~23, a\* ~0.34 and b\* ~3.34. The values of the coordinates indicated the marked presence of  
220 redness and yellowness tones, thus confirming the brownish colour.

221 FS and RSs samples were prepared keeping constant pH and °Brix to replicate the industrial process.  
222 In particular,  $\text{pH} = 3.6 \pm 0.1$  and  $^{\circ}\text{Brix} = 72 \pm 1$  were reached in all samples increasing the citric acid  
223 content and prolonging (where necessary) the cooking time, respectively. pH and °Brix were also  
224 monitored throughout the entire storage time (data not showed) indicating significant but slight  
225 changes and remaining in the desired range.

226

#### 227 **3.1 Nutritional label information**

228 Pillar of the study was the development of a filling formulation with an improved nutritional profile  
229 in terms of lower sugar and higher dietary fibre contents, if compared with a standard filling  
230 formulation. The nutritional labels of FS and RSs are reported in Table 2.

231 Energy decreased remarkably with the increase of the fibre syrup moving from 964 KJ/230 Kcal of  
232 FS to 831 KJ/198 Kcal, 724 KJ/173 Kcal and 620 KJ/148 Kcal of RS30, RS50 and RS70, respectively.

233 The energy decrease was associated to the decrease of the carbohydrates in favour of the dietary fibres  
234 which have a lower energy conversion factor as indicated in the EU Regulation on labelling of food  
235 products (Regulation (EU) No 1169/2001). Moreover, RSs presented a sugar content reduced by 30%  
236 (RS30, from 55.8 g/100 g to 39 g/100 g), 50% (RS50, from 55.8 g/100 g to 27.5 g/100 g) and 70%  
237 (RS70, from 55.8 g/100 g to 17 g/100) if compared with FS. A slight increase of protein content was  
238 observed for RS50 and RS70 (respectively 0.6 g/100 g and 0.9 g/100 g) due to the increase of the  
239 fibre syrup in the formulation which intrinsically has a low amount of residual protein content. The  
240 increase of the fibre syrup led to an increase in the fibre content in the recipe from 1 g/100 g of FS to  
241 15 g/100 g, 22.5 g/100 g and 30 g/100 g for RS30, RS50 and RS70, respectively. The decrease of  
242 sugar and the increase of fibre contents would allow to label all the RSs with the double nutritional  
243 claims “reduced in sugar” and “high in fibre” based on the EU regulation on nutritional and health  
244 claims (Regulation (EC) No 1924/2006).

245

### 246 **3.2 Physico-chemical characterization**

247 Product stability at rheological, chemical and microbiological level is strongly related to water  
248 activity ( $a_w$ ) and moisture content (MC). Both parameters for all samples during storage are reported  
249 in Table 3 while the statistical outputs can be found in Table 4.

250 MC was affected by recipe (R) increasing with the decrease of sugar in the recipe (from  $\approx 20\%$  in FS  
251 to  $\approx 23\%$  in RS70 at  $t_0$ ). Similarly,  $a_w$  was highly affected by R showing an increase with the decrease  
252 of sugar moving from  $\approx 0.80$  in FS to  $\approx 0.87$  in RS70. Similar trends were noticed at all storage  
253 temperatures and times. These results were related to the water content ( $\approx 25\%$  g water/100 g sample)  
254 of the fibre syrup used to partially replace sugar and/or to its different interaction with water than  
255 those developed by sugar. Indeed, sugar is highly hygroscopic and has higher capacity than fibre to  
256 bind water thanks to the higher amount of available free hydroxyl group compared to long chain  
257 polysaccharides. The increase of  $a_w$  and MC when sugar was replaced by vegetable fibres was  
258 previously reported in studies conducted on cakes, muffin and fruit jellies (Milner et al., 2020; Riedel

259 et al., 2015; Zahn et al., 2013). However, the increase of both parameters does not affect product  
260 microbiological stability because the product is acidic (pH ~3.6) and it is stabilised with a hot filling  
261 process. The use of fiber syrup as sugar substitute in non-acidic products should envisage acid  
262 regulation to ensure microbiological safety. MC was affected also by St which slightly fluctuated  
263 during storage probably due to a macroscopic water redistribution in the product. The storage  
264 temperature did not affect neither the moisture content and the water activity with only a slightly  
265 significant difference for FS and RS30 at t60.

266 Fruit fillings rheological properties were assessed using both empirical and fundamental techniques  
267 in order to verify agreement between the two analytical approaches providing useful information to  
268 those food industries able to implement only cheaper and easier rheological methods. Fillings'  
269 firmness and adhesiveness parameters (Figure 1) aimed to give some information related to the  
270 mouthfeel of the product which is an important quality characteristic of semi-solid foods as filling.  
271 These food materials indeed shall not be chewed and their texture features are directly perceived in  
272 the mouth by tongue receptors (Agudelo et al., 2015a). Three-way ANOVA (Table 4) highlighted  
273 that firmness and adhesiveness were primarily affected by R with a significant increase of both  
274 parameters with the sugar decrease in the recipes. The increase of firmness and adhesiveness was  
275 likely affected by the increase of the fibre syrup which bulking effect strongly impacted on the overall  
276 structure. This phenomenon is probably due to the interactions among the polysaccharide long chains  
277 present in the syrup which probably affected the macrostructure. At t30, t60 and t180, FS, RS30 and  
278 RS50 had comparable firmness and adhesiveness while RS70 was harder and more adhesive than all  
279 other samples.

280 Flow properties play a fundamental role in the quality characteristics of filling. Its fluidity and  
281 structure may modulate the flavour perception in the mouth and therefore influence consumer  
282 acceptability; moreover, pumping and baking phase at industrial level may be strongly affected by a  
283 change in system fluidity (Agudelo et al., 2015a; Razak et al., 2018; Wei et al., 2001). Flow curves

284 fitting allowed to calculate the non-Newtonian index ( $n$ , data not showed) and the consistency  
285 coefficient ( $K$ , Table 4, Figure 2).

286  $n$  index of fillings fell between 0.33-0.40, characterising the product as pseudo plastic fluid ( $n < 1$ ), as  
287 previously reported in fruit filling (Nalawade et al., 2017; Wei et al., 2001).  $n$  index was more affected  
288 by St with only slight significative variation during storage (Table 4).  $K$  was instead strongly  
289 influenced by R showing a significantly increase with the reduction of sugar. Higher  $K$  at all storage  
290 times and temperatures was observed for RS70 if compared to other samples. A good positive relation  
291 ( $r^2 = 0.96$ ) was found between firmness and  $K$ , probing accordance between empirical and  
292 fundamental rheological analysis. Overall, the fibre syrup used in this work increased firmness and  
293  $K$  when used to reduce sugar above 30%. On the contrary, polydextrose (E1200) was found to  
294 marginally affect the rheological properties of fruit filling when used to completely replace sugar  
295 (Agudelo et al., 2015b).

296 Consumer acceptability is strongly influenced by the colour which is one of the most important  
297 appearance factors, influencing also the flavour perception and the overall purchase decision (Pathare  
298 et al., 2013). The colour properties of fillings were therefore analysed (Table 5).

299 Colour was most affected by St (Table 4): a significant decrease of all colour parameters was noticed  
300 at both storage temperatures in all samples (more pronounced in FS). A decrease of  $L^*$ ,  $a^*$  and  $b^*$   
301 during storage was observed also in previous studies on apricot (Touati et al., 2014) and strawberry  
302 jam (Wicklund et al., 2005). The darkening of jam products during storage has been associated to the  
303 fruit anthocyanidins degradation. Anthocyanidins originate from anthocyanins degradation which  
304 occurs during thermal and mechanical production steps. Anthocyanidins are less stable than  
305 anthocyanins to light and oxygen and consequently more prone to browning reactions (Wicklund et  
306 al., 2005).

307 Colour was less affected by R (Table 4) where in fresh products a significative decrease of all  
308 parameters was noticed with the increase of the fibre syrup due to its intrinsic brownish colour. Colour  
309 changes as a function of St and R were also highlighted by the  $\Delta E$  values (Table 5). However, it is

310 important to remark that all the formulations studied did not contain any food colouring ingredients  
311 which could be included in the formulation in the industrial scale up in order to stabilise the product  
312 during storage and to counterbalance the presence of the fibre syrup.

313 Other fruit filling' quality features are the stability – preservation of the dimension at high temperature  
314 during baking (Agudelo et al., 2014; Young et al., 2003) and the absence of water syneresis as a  
315 migration of water from the fruit filling to the dough may lead to product inhomogeneity and  
316 stickiness (Cropotova et al., 2016). All filling formulations produced did not show water syneresis  
317 during storage. The absence of water syneresis also in the RSs in which MC and  $a_w$  were higher than  
318 in FS indicates that the fibre syrup had a positive technological role acting as stabilising ingredient.  
319 Bake stability results (Table 6) indicated its addiction by St showing a decrease during storage in all  
320 samples. Moreover, only at t0, formulations containing the fibre syrup showed a significantly increase  
321 of their bake stability index if compared with FS highlighting an improvement of this quality indicator  
322 in the fresh product.

323

### 324 **3.3 Sensory analysis**

325 All the fruit fillings were considered acceptable by the consumers (overall acceptability scores higher  
326 than 5 in all cases) with FS and RS30 considered the most preferred (score  $\approx 7$ ) (Figure 3). The lowest  
327 scores were attributed to RS70, in particular for consistency which was evaluated with a score  $< 5$   
328 indicating a worsening of the fruit filling structure probably due to its higher firmness, adhesiveness  
329 and K compared to the other formulations. No significative differences for sensory attributes were  
330 registered during storage. These findings are encouraging considering that the product sensory  
331 stability for long lasting shelf-life is a relevant quality feature. A better elucidation of the fillings'  
332 consumers perception was assessed using a CATA test. The two dimensions of the factor plane  
333 representing the CATA test conducted at t0 (Figure 4) explained  $\approx 93\%$  of the variance, with  
334 dimension 1 explaining  $\approx 80\%$  and dimension 2 explaining  $\approx 13\%$ . IDEAL fruit filling was described  
335 as fluid, pleasant consistency, melty, sweet, apricot taste, good aftertaste, good taste. Attributes as

336 “melty”, “sweet” and “fruity” were also found in the IDEAL filling in the study of (Agudelo et al.,  
337 2015b). FS and RS30 were described by similar attributes: pleasant colour, orange, shiny, very sweet.  
338 On the opposite, RS50 and RS70 were characterised by negative attributes as jelly, vegetal taste,  
339 mediocre taste, sticky and unpleasant colour (RS50), and opaque, acid, slightly sweet, bad aftertaste,  
340 unpleasant consistency, brown, bad taste, sandy and bitter (RS70). The negative attributes related to  
341 consistency for RS50 and RS70 highlighted that the use of the syrup in high amount led to a  
342 detrimental effect on product texture increasing the “jelly” perception which is the opposite of the  
343 fluid attribute applied for the IDEAL product. Consumers’ appreciation for the fruit filling fluid  
344 consistency was previously reported (Agudelo et al., 2015b). Overall, RS30 was the most appreciated  
345 reduced-sugar formulation based on both acceptability and CATA test, particularly for its texture  
346 properties. No remarkably differences on samples attributes were noticed during storage confirming  
347 the results of the acceptability test.

348

#### 349 **4. Conclusions**

350 “Sugar reduced” and “high in fibre” claims could be used to label reformulated fruit fillings by means  
351 of the use of a syrup based on chickpea and maize fibre as sugar replacer. The use of the syrup  
352 increased the  $a_w$ , MC as well as firmness, adhesiveness, K consistency coefficient and bake stability,  
353 while decreased the colour coordinates  $L^*$ ,  $a^*$ ,  $b^*$ . Storage time mainly affected the colour and the  
354 bake stability of all fruit fillings while the storage temperature presented a little or negligible effect  
355 on all studied parameters. When sugar was reduced by 30% the overall physicochemical and sensory  
356 properties of the reformulated fruit filling were found to be similar to the full-sugar counterpart.  
357 The use of the fibre syrup as clean label ingredient was found to be a valuable ingredient on a  
358 technological standpoint, allowing to improve the nutritional profile of the product and to partially  
359 replace the bulking agent role of sugar.

360

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363

#### 364 **Conflict of interests**

365 AC was involved in the research as Industrial PhD student. Universities involved in this research have  
366 not received any funding.

367

#### 368 **Ethical guidelines statement**

369 All judges were previously informed about the scope of the research and of its non-commercial  
370 purpose, as well as their anonymous and voluntary participation. Moreover, judges were informed of  
371 the composition of the fruit fillings to exclude any allergic subject. Judges were also informed about  
372 the possible use of the data raised by the study for any scientific or informative communication.

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461 fibres for partial sucrose replacement in muffins. *LWT – Food Sci. Technol.*, 50(2), 695-701.

463 Table 1. Fruit filling recipes (% wt).

	FS	RS30	RS50	RS70	464
Sucrose	32	30.6	19.3	8.3	465
Glucose syrup	20	-	-	-	466
MELTEC®	-	21.4	32.7	43.7	467
Water	26.9	26.8	26.75	26.72	468
Apricot jam	20	20	20	20	469
Pectin	0.8	0.8	0.8	0.8	470
Citric acid	0.14	0.24	0.29	0.32	471
Tricalcium citrate	0.08	0.08	0.08	0.08	472
Potassium sorbate	0.05	0.05	0.05	0.05	473
Apricot flavour	0.03	0.03	0.03	0.03	

474 FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.  
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476 Table 2. Nutritional composition based on Reg EU 1169/2011 of fruit fillings at different sucrose content (g/100g).

	<b>FS</b>	<b>RS30</b>	<b>RS50</b>	<b>RS70</b>	
<b>Energy (kJ)</b>	964	831	724	620	477
<b>Energy (kcal)</b>	230	198	173	148	478
<b>Fat</b>	0	0	0	0	479
<b>-of which saturated</b>	0	0	0	0	480
<b>Carbohydrates</b>	57.0	41	30.5	20	481
<b>-of which sugars</b>	55.8	39	27.5	17	482
<b>Fibre</b>	1.0	15.0	22.5	30.0	483
<b>Protein</b>	0	0	0.6	0.9	484
<b>Salt</b>	0	0	0	0	485

FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

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Table 3. Moisture content (MC), water activity ( $a_w$ ) of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

		Moisture content (MC) g H <sub>2</sub> O/ 100 g of sample			
		t0	t30	t60	t180
5 °C	FS	20.50 ±0.02 bB	22.50 ±0.01 bA	23.50 ±0.01 bA*	22.83 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.83 ±0.01 abA	24.17 ±0.01abA*	23.83 ±0.01 abA
	RS50	22.50±0.01 aB	24.50±0.02 aA	25.00±0.02 aA	24.67±0.02 aA
	RS70	23.00±0.01aB	23.67±0.01 abB	25.00±0.01 aA	23.67±0.01 abB
25° C	FS	20.50 ±0.02 bB	22.00 ±0.01 bA	22.83 ±0.01 bA*	22.33 ±0.01 bA
	RS30	22.67 ±0.01 aB	23.33 ±0.01 aAB	23.67 ±0.01 bA*	23.83 ±0.01 aA
	RS50	22.50±0.01 aB	24.33 ±0.01 aA	24.67 ±0.01 aA	24.00 ±0.01 aA
	RS70	23.00±0.01aB	23.67±0.01 aB	24.67±0.01 aA	23.83±0.01 aAB
		Water activity ( $a_w$ )			
		t0	t30	t60	t 180
5 °C	FS	0.800 ±0.010 dA	0.801 ±0.014 dA	0.805 ±0.007 dA	0.794 ±0.004 dA
	RS30	0.836 ±0.007 cAB	0.836 ±0.009 cAB	0.842 ±0.004 cA	0.832 ±0.003 cB
	RS50	0.861 ±0.005 bA	0.858 ±0.005 bA	0.864 ±0.005 bA	0.857 ±0.008 bA
	RS70	0.874 ±0.003 aA	0.874 ±0.002 aA	0.876 ±0.003 aA	0.866 ±0.003 aB
25° C	FS	0.800 ±0.010 dA	0.798 ±0.009 dA	0.804 ±0.010 dA	0.784 ±0.004 dB
	RS30	0.836 ±0.007 cA	0.833 ±0.009 cA	0.839 ±0.003 cA	0.824 ±0.006 cB
	RS50	0.861 ±0.005 bA	0.857 ±0.004 bA	0.858 ±0.010 bA	0.846 ±0.010 bB
	RS70	0.874 ±0.003 aA	0.871 ±0.004 aA	0.875 ±0.003 aA	0.865 ±0.002 aB

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All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample ( $p \leq 0.05$ ), where the small letters due to the sugar content, capital letter due to the time of storage and \* due to temperature of storage. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

495 Table 4. Partition of the total variance of sum square (SS%) of each single factor (R: recipe, St: storage time; ST: storage  
 496 temperature) and their interactions for each parameter studied. In brackets the significance ( $p < 0.05$ ) of the influence of individual  
 497 factors and their interactions.

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	R	St	ST	R*St	R*ST	St*ST	R*St*ST
$a_w$	96.6 (0.00)	2.5 (0.00)	0.3 (0.00)	0.1 (0.90)	0.1 (0.71)	0.2 (0.04)	0.2 (0.89)
MC	45.6 (0.00)	45.7 (0.00)	1.3 (0.07)	5.8 (0.12)	0.4 (0.81)	0.6 (0.71)	0.6 (0.99)
Firmness	48.5 (0.00)	39.4 (0.00)	2.4 (0.00)	5.0 (0.00)	0.3 (0.63)	4.0 (0.00)	0.4 (0.98)
Adhesiveness	63.4 (0.00)	21.5 (0.00)	5.0 (0.00)	4.7 (0.00)	0.3 (0.51)	4.8 (0.00)	0.3 (0.98)
$n$	17.8 (0.00)	37.8 (0.00)	11.1 (0.00)	15.5 (0.82)	0.0 (0.00)	15.6 (0.00)	2.2 (0.82)
K	78.7 (0.00)	9.7 (0.00)	4.9 (0.00)	1.0 (0.83)	0.3 (0.65)	4.5 (0.00)	0.9 (0.89)
L*	25.9 (0.00)	64.6 (0.00)	1.6 (0.00)	5.7 (0.00)	0.2 (0.63)	1.7 (0.00)	0.3 (0.40)
a*	29.5 (0.00)	57.5 (0.00)	0.2 (0.05)	2.5 (0.00)	0.4 (0.01)	8.8 (0.00)	1.1 (0.00)
b*	30.7 (0.00)	55.6 (0.00)	4.4 (0.00)	5.3 (0.00)	0.4 (0.00)	3.3 (0.00)	0.3 (0.00)
Bake stability	2.9 (0.00)	85.0 (0.00)	2.2 (0.00)	5.1 (0.00)	1.6 (0.00)	1.1 (0.00)	2.1 (0.00)

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Table 5. Color parameters of fruit fillings at different sugar content during storage (t0, t30, t60, t180) at different temperatures (5°C, 25°C).

	t0		t30				t60				t180				
			5°C		25°C		5°C		25°C		5°C		25°C		
	$\Delta E$		$\Delta E$		$\Delta E$		$\Delta E$		$\Delta E$		$\Delta E$		$\Delta E$		
FS															
$L^*$	35.42 ± 1.70	aA	33.16 ± 1.27	aB	33.71 ± 1.89	aB	30.71 ± 1.35	aC	30.58 ± 1.39	aC	30.51 ± 1.16	aC	28.48 ± 1.01	abD	
$a^*$	10.71 ± 1.28	aA	-	8.44 ± 1.28	aB	-	9.19 ± 1.91	aB	-	6.53 ± 1.24	aC	-	6.36 ± 1.14	aC*	
$b^*$	15.00 ± 2.40	aA	11.80 ± 1.83	aB	13.35 ± 2.72	aB	8.50 ± 1.39	aC	8.03 ± 1.85	aC	8.27 ± 1.56	aC	5.42 ± 0.99	aD	
$\Delta E$	-		4.5		2.8		9.1		9.8		9.4		13.2		
RS30															
$L^*$	32.40 ± 1.50	aA	30.98 ± 0.42	bB	30.86 ± 0.75	bB	29.57 ± 0.78	bC	29.43 ± 1.10	bC	29.52 ± 1.24	bC	27.89 ± 1.05	abD	
$a^*$	9.18 ± 1.78	aA	5.3	7.66 ± 0.80	bB	3.9	8.51 ± 1.59	aA	5.2	5.25 ± 1.32	bC	2.18	5.16 ± 1.94	abB	
$b^*$	10.85 ± 2.02	aA	8.71 ± 0.76	bB	9.03 ± 1.34	bB	7.16 ± 0.95	bC	6.03 ± 1.50	bC	7.70 ± 1.47	aC	2.4	6.88 ± 1.25	aD*
$\Delta E$	-		3.0		2.5		6.1		6.9		4.8		9.6	1.6	
RS50															
$L^*$	31.76 ± 1.01	aA	29.70 ± 0.54	cB	29.71 ± 0.52	cB	28.97 ± 0.4	cC*	28.28 ± 0.37	cC*	28.28 ± 0.85	cD	27.74 ± 1.14	bC	
$a^*$	8.56 ± 1.36	aA	6.8	6.07 ± 0.90	cB*	6.3	6.76 ± 0.71	cB*	7.8	4.10 ± 0.62	cC	4.0	4.35 ± 1.15	bcC	
$b^*$	9.65 ± 1.26	aA	7.12 ± 0.91	cB	7.10 ± 0.58	cB	5.82 ± 0.64	cC*	5.34 ± 0.48	cC*	5.66 ± 1.04	bC	3.8	4.78 ± 0.95	bC*
$\Delta E$	-		4.1		3.7		6.5		7.0		6.5		8.1	1.7	
RS70															
$L^*$	30.75 ± 1.12	cA	30.26 ± 1.0	cA*	29.53 ± 0.4	cB*	28.52 ± 0.3	cB*	28.17 ± 0.40	cC*	28.42 ± 0.92	cB	28.90 ± 2.2	aBC	
$a^*$	6.91 ± 1.00	cA	9.2	5.51 ± 0.90	cB	6.1	5.92 ± 0.57	cB	8.5	3.74 ± 1.12	cC	4.7	3.45 ± 0.39	cC	
$b^*$	8.00 ± 0.69	cA	7.25 ± 1.26	cB	6.68 ± 0.53	cB	5.42 ± 0.73	cC*	4.60 ± 0.41	cC	5.13 ± 0.78	bC	4.8	4.13 ± 0.75	bC*
$\Delta E$	-		1.7		2.0		4.7		5.5		4.6		6.9	3.4	

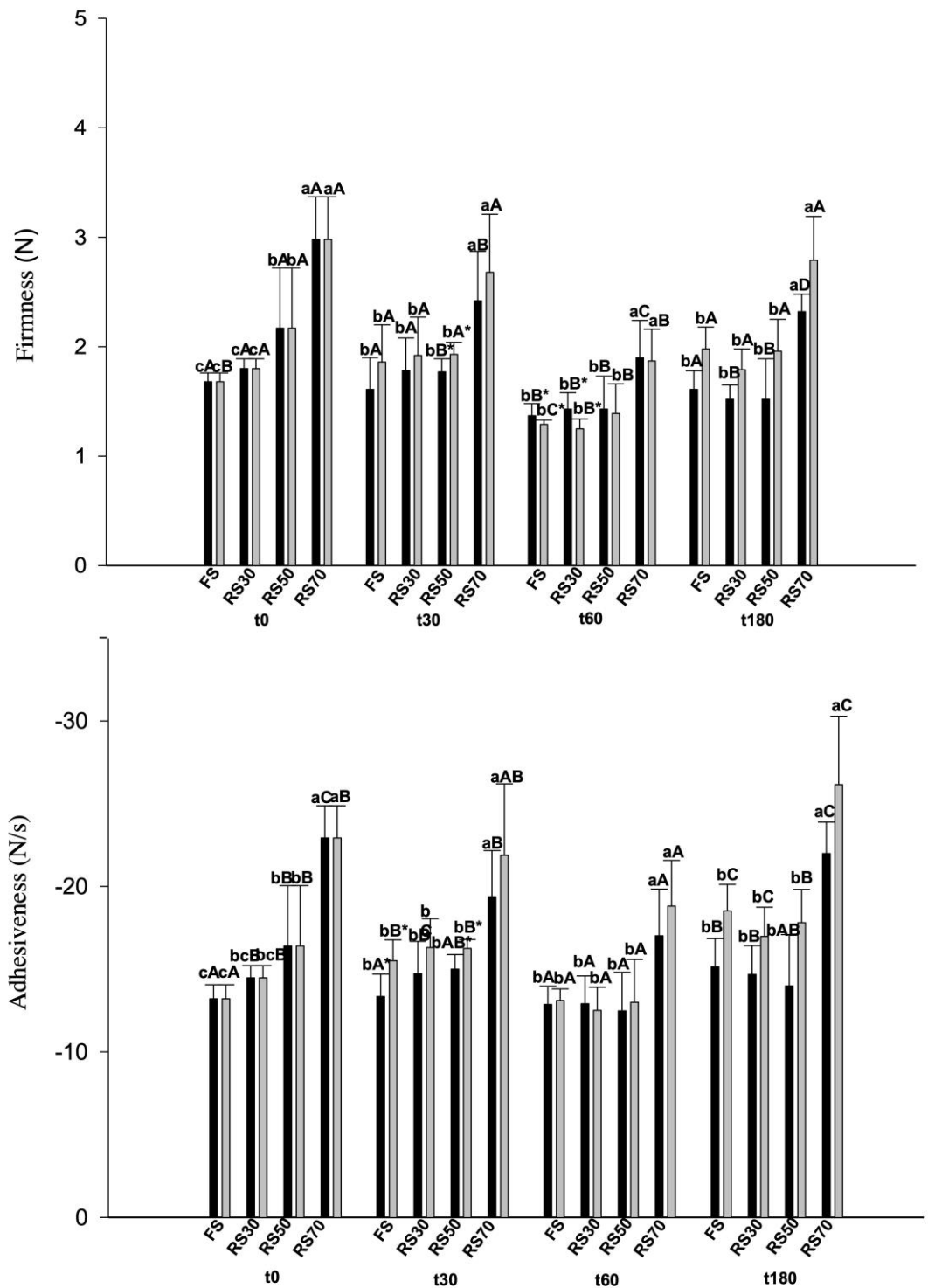
All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among samples ( $p \leq 0.05$ ), where the small letters due to the sugar content, capital letter due to the time of storage and \* due to temperature of storage. Vertically are reported  $\Delta E$  associated to the reformulation while horizontally  $\Delta E$  associated to the storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

502 Table 6. Bake stability of fruit filling at different sugar content during storage (t0, t30, t60, t180) at different temperature (5°C,  
 503 25°C).

		Bake stability (%)			
		t0	t30	t60	t180
5 °C	FS	77.75 ± 0.10 bA	69.75 ± 0.12 aB	69.13 ± 0.05 aB	62.38 ± 0.09 aC
	RS30	81.58 ± 0.05 aA	75.54 ± 0.13 aB	68.63 ± 0.07 aC	60.71 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	74.04 ± 0.10 aB	71.29 ± 0.10 aB*	58.46 ± 0.08 aC
	RS70	85.04 ± 0.05 aA	76.04 ± 0.10 aB	69.67 ± 0.09 aC	60.21 ± 0.07 aD
25° C	FS	77.75 ± 0.10 bA	74.67 ± 0.11 aA	69.08 ± 0.08 aB	65.33 ± 0.10 aB
	RS30	81.58 ± 0.05 abA	76.71 ± 0.07 aB	69.13 ± 0.08 aC	63.46 ± 0.09 aD
	RS50	81.13 ± 0.05 aA	76.25 ± 0.04 aB	65.29 ± 0.05 aB	56.54 ± 0.08 aB
	RS70	85.04 ± 0.05 aA	72.04 ± 0.08 aB	65.17 ± 0.08 aC	62.13 ± 0.09 aC

504 All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample  
 505 (p ≤ 0.05), where the small letters due to the sugar content, capital letter due to storage time and \* due to storage temperature. FS: full  
 506 sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

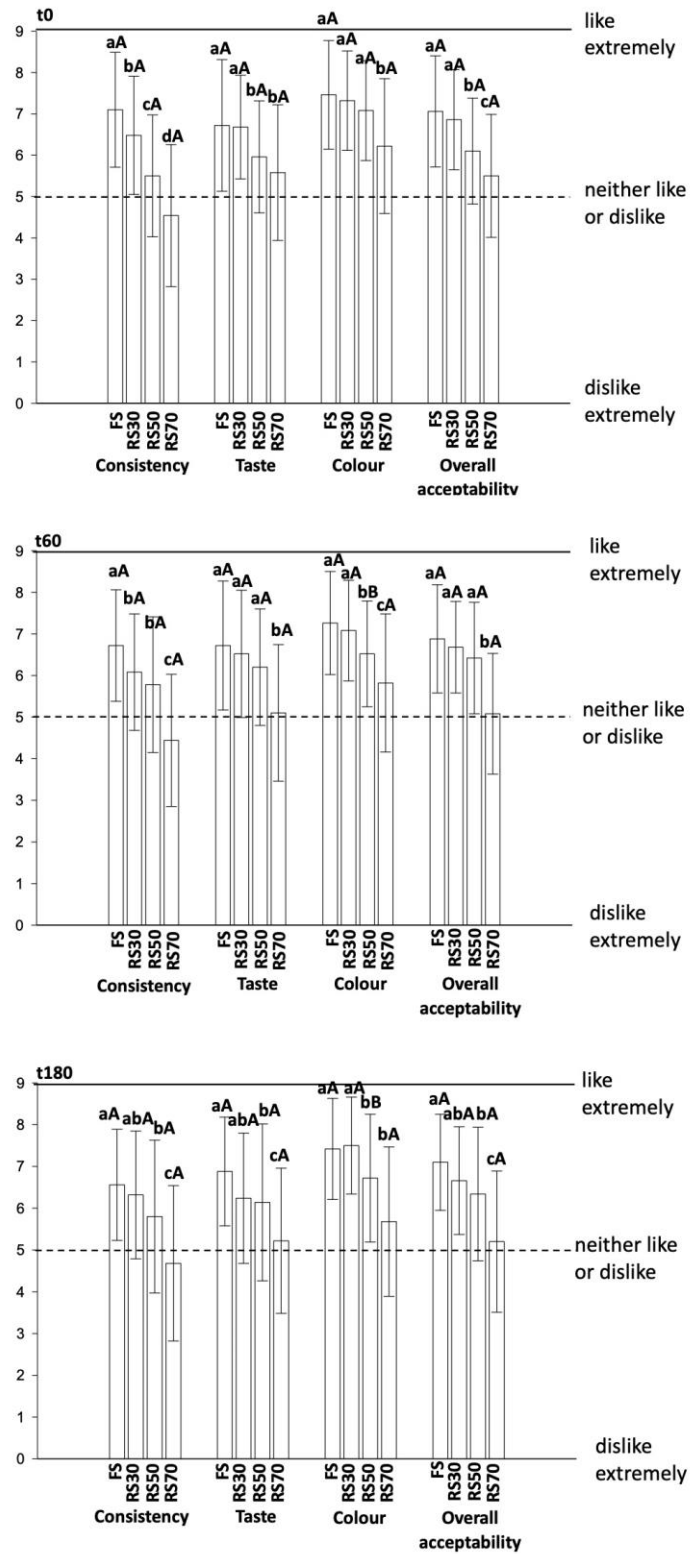
507 Figure 1. Firmness and adhesiveness of fruit fillings at variable sucrose content during storage at different temperatures (black: 508 5°C, grey: 25°C). Different letters close to the bar indicated significant difference among sample ( $p \leq 0.05$ ) where the small 509 letters were due to the sugar content while capital letter to storage time, and \* symbol represented the difference due to storage 510 temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.



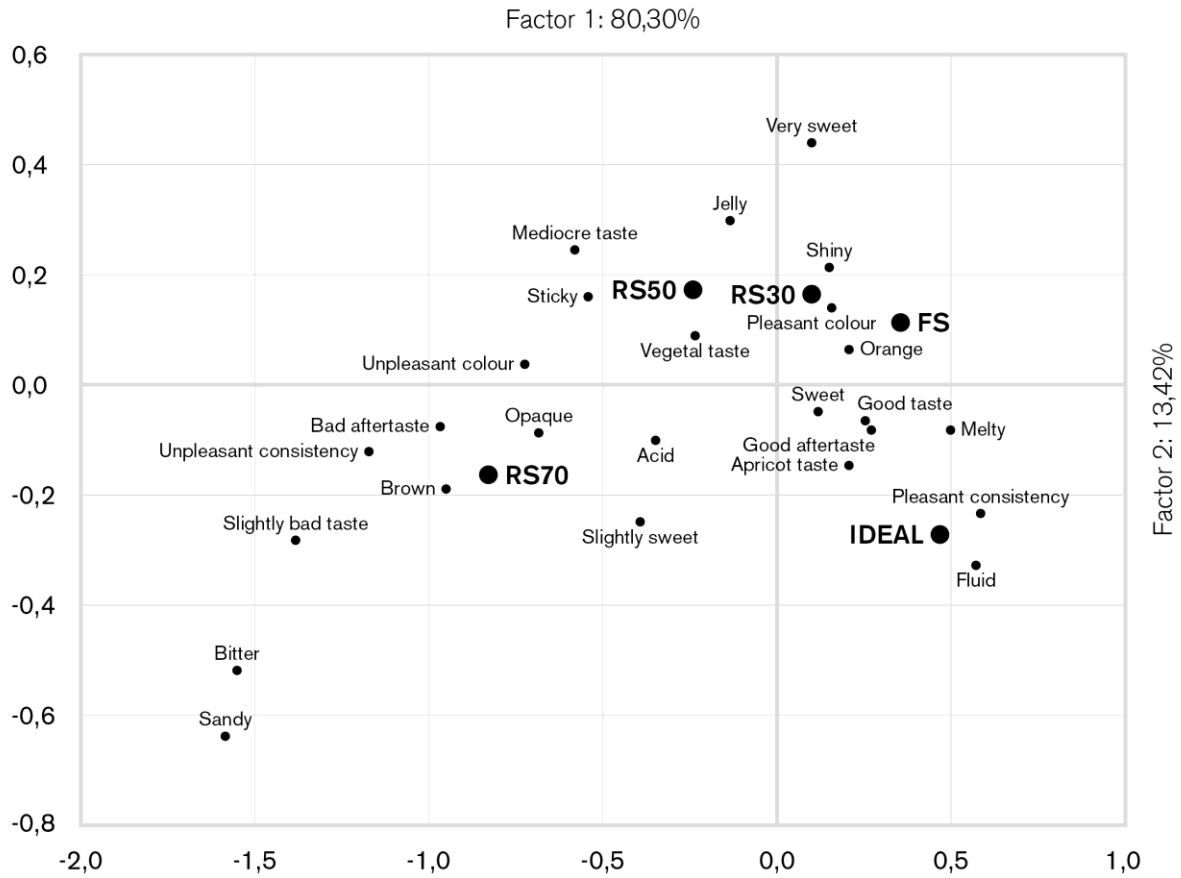
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519 Figure 3. Sensory scores for consistency, taste, colour and overall acceptability of fruit filling at variable sucrose content.  
 520 Different letters close to the bar indicate significant difference among sample ( $p \leq 0.05$ ) where the small letters due to the sugar  
 521 content, capital letter due to storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70%  
 522 sugar reduction.



524 Figure 4. Correspondence analysis of the CATA test data of fruit filling formulated with  
 525 different sucrose content. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar  
 526 reduction; RS70: 70% sugar reduction.  
 527



528

## Implications for gastronomy

1  
2 Nowadays, one of the major trends in food science and gastronomy in the food reformulating area is  
3  
4 the improvement of the nutritional value by the reduction of sugar. Due to the crucial role of sugar in  
5  
6 food quality, its reduction is challenging. This problem is amplified by another trend that is the  
7  
8 consumer demand for clean ingredients and labels which ask for not E numbers - sugar substitutes.  
9  
10 The fibre syrup studied in this work can be used in different gastronomy applications such as fruit  
11  
12 filling, jam, jellies and similar to replace the bulking agent functionality of sugar particularly where  
13  
14 there is a clean label need and/or when “Sugar reduced” and “high in fibre” claims are pursued. In  
15  
16 addition, the facility of using the fibre syrup as substitute (partially) of glucose syrup, sucrose and  
17  
18 glucose makes interest and easy its use in pastry shops or in catering facilities to produce reduced in  
19  
20 sugar and high in fiber fruit filling which can be used in products as croissant, doughnuts, cakes.”  
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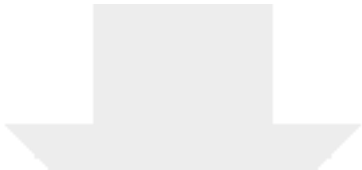
This work was part of a wider project within an Industrial PhD project. The author Alessandro Carcelli was involved in the research as Industrial PhD student. Universities involved in this research have not received any funding to carry out the work.

**Alessandro Carcelli:** Methodology, Conceptualization, Formal Analysis, Investigation, Visualization, Writing – Original Draft

**Anna Albertini:** Methodology, Conceptualization, Investigation, Formal Analysis, Visualization

**Elena Vittadini:** Methodology, Writing – Review and Editing

**Eleonora Carini:** Methodology, Conceptualization, Investigation, Resources, Writing – Review and Editing, Supervision, Project Administration



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