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

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Original

A fibre syrup for the sugar reduction in fruit filling for bakery application / Carcelli, A.; Albertini, A.; Vittadini, E.; Carini, E.. - In: INTERNATIONAL JOURNAL OF GASTRONOMY AND FOOD SCIENCE. - ISSN 1878-450X. - 28:(2022), p. 100545.100545. [10.1016/j.ijgfs.2022.100545]

Availability:

This version is available at: 11381/2934272 since: 2025-01-13T17:42:49Z

Publisher: AZTI-Tecnalia

Published DOI:10.1016/j.ijgfs.2022.100545

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(Article begins on next page)

International Journal of Gastronomy and Food Science A fibre syrup for the sugar reduction in fruit filling for bakery application --Manuscript Draft--

Manuscript Number:	IJGFS-D-22-00043R3
Article Type:	Research Paper
Section/Category:	Science and gastronomy (chemistry, engineering, sensory science, microbiology)
Keywords:	Fruit filling; sugar reduction; fibre syrup; dietary fibre
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Abstract:	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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Response to Reviewers:	

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.

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28 Abstract

Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new fibre syrup based on corn (Zea mays) 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 firmness, 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.

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

54 **1. Introduction**

In Europe, the estimated daily energy intake from sugar ranges between 15-21% in adult and between 55 16%-26% in children of the total energy intake (Azaïs-Braesco et al., 2017). These values are not in 56 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 governments are informing consumers on the adverse effect of a high sugar diet. As a result, the 61 request of reduced-sugar products on the market is increasing (FIE Global, 2020). 62

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

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

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

Cicer arietinum seed) was previously characterized and tested as sugar replacer in cookies and ripple
sauces with encouraging results (Carcelli, Alberti et al., 2021; Carcelli, Suo et al., 2021).

In this work, same commercial fibre syrup was tested as buking agent ingredient to develop reducedsugar fruit filling formulations. Fruit fillings with different reduced-sugar levels were developed and 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 Low Molecular Weight Dietary Fiber (AOAC method 2009.01)], with a sugar content < 1.0% (g 95 96 sugar/100 g sample), and a moisture content $\approx 25\%$ (g water/100 g sample). The commercial fiber syrup was also characterized in terms of Brix degrees (portable refractometer HB 95, Lega Italy, 97 98 Ravenna, Italy), water activity at 25°C (aw, Aqualab 4 TE, Decagon Devices Inc., Pullman, WA, USA), pH (potentiometer pH7+DHS Food, XS Instruments, Modena, Italy) and colour. Colour 99 100 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.

Other ingredients used in the fruit filling recipes were: low-methoxyl (LM) pectin Classic AB 902
(Herbstreith&Fox KG, Werder, Germany), glucose syrup 60 dextrose equivalent DE "Glucoplus
361" (Uniglad Ingredienti, Cuneo, Italy), tricalcium citrate (Giusto Faravelli, Milano, Italy),
potassium sorbate (Giusto Faravelli, Milano, Italy), crystalline sucrose (British sugar, Peterborough,
UK), apricot jam (Rogelfrut, Cuneo, Italy), citric acid (Brenntag, Milano, Italy), apricot flavour
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
- 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.
- At least three measurements were taken for each formulation for a total of six determinations at eachstorage time.

151 2.3.4 Textural and rheological properties

- Texture properties were determined using TA.XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK) equipped with a P/20 probe. A cylindrical container (58 X 70 mm) was completely 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.

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

164

 $\sigma = K\gamma^n$

165 where σ is the shear stress (Pa), γ is the shear rate (s⁻¹), K is the consistency coefficient (Pa*sⁿ) and *n* 166 the non-Newtonian index (dimensionless).

167 Three measurements were performed for each batch for a total of six determinations for each168 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; ΔE 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

Syneresis was measured as described by Cropotova and co-workers (Cropotova et al., 2009). Samples of 5 g (F₀) were transferred into a 50 ml falcon tube, sealed with plastic cap and centrifuged at 3000 rpm for 20 min (centrifuge 5910R, Eppendorf, Milan, Italy). The weight of the supernatant fraction (F₁) was measured and grade of syneresis was calculated as percentage (%) = (F₁/F₀)*100. Three replicates for each batch for a total of six determinations for each formulation were carried out. Bake stability was evaluated following Young and colleagues with slight modifications (Young et al., 2003). Fruit filling samples of 10 g were placed into a circular mould (\emptyset 35 mm) on a 7x7 cm layer of short crust. On the circular sample obtained, 4 points have been marked on the external part to measure the pre- and post-baking (200° C, 10 min, 903.008.05, IKEA, Leida, Netherlands) diameter. Bake stability percentage (B.S.%) has been calculated according with:

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

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

189 Three measurements were performed for each batch changing the position of the short crust in the190 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

Data were processed with a three-way ANOVA using three fixed factors: recipe (R), storage time (St) and storage temperature (ST). The evaluation of single factor and their interactions in the variability of each parameter was obtained with the partition of total variance of sum square (SS%). Significant differences ($p \le 0.05$) among different samples were assessed by one-way-analysis of variance (ANOVA) with a Duncan post-hoc test using an IBM SPSS statistical software (Version 24.0, SPSS Inc., Armonk, New York, USA). The contingency table of CATA dataset was obtained
on the basis of samples and attributes. A correspondence analysis was performed to summarize the
relationship between samples and attributes using Statistica software (Version.13.3, TIBCO Software
Inc.).

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213 3. Results and discussion

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

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

226

227 3.1 Nutritional label information

- Pillar of the study was the development of a filling formulation with an improved nutritional profile
 in terms of lower sugar and higher dietary fibre contents, if compared with a standard filling
 formulation. The nutritional labels of FS and RSs are reported in Table 2.
- Energy decreased remarkably with the increase of the fibre syrup moving from 964 KJ/230 Kcal of
 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

Product stability at rheological, chemical and microbiological level is strongly related to water activity (a_w) and moisture content (MC). Both parameters for all samples during storage are reported 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 ≈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 ≈0.80 in FS to ≈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) of the fibre syrup used to partially replace sugar and/or to its different interaction with water than 254 255 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 et al., 2015; Zahn et al., 2013). However, the increase of both parameters does not affect product microbiological stability because the product is acidic (pH ~3.6) and it is stabilised with a hot filling process. The use of fiber syrup as sugar substitute in non-acidic products should envisage acid regulation to ensure microbiological safety. MC was affected also by St which slightly fluctuated during storage probably due to a macroscopic water redistribution in the product. The storage temperature did not affect neither the moisture content and the water activity with only a slightly significant difference for FS and RS30 at t60.

Fruit fillings rheological properties were assessed using both empirical and fundamental techniques 266 267 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.

Flow properties play a fundamental role in the quality characteristics of filling. Its fluidity and structure may modulate the flavour perception in the mouth and therefore influence consumer acceptability; moreover, pumping and baking phase at industrial level may be strongly affected by a change in system fluidity (Agudelo et al., 2015a; Razak et al., 2018; Wei et al., 2001). Flow curves fitting allowed to calculate the non-Newtonian index (n, data not showed) and the consistencycoefficient (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 ΔE values (Table 5). However, it is important to remark that all the formulations studied did not contain any food colouring ingredients
which could be included in the formulation in the industrial scale up in order to stabilise the product
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 than 5 in all cases) with FS and RS30 considered the most preferred (score ≈7) (Figure 3). The lowest 326 327 scores were attributed to RS70, in particular for consistency which was evaluated with a score < 5328 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 ≈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

361 Acknowledgments

- 362 The Authors would like to thank Francesca Petrelli for carrying out part of the experimental work.
- 363

364 Conflict of interests

- AC was involved in the research as Industrial PhD student. Universities involved in this research have
 not received any funding.
- 367

368 Ethical guidelines statement

- All judges were previously informed about the scope of the research and of its non-commercial purpose, as well as their anonymous and voluntary participation. Moreover, judges were informed of the composition of the fruit fillings to exclude any allergic subject. Judges were also informed about the possible use of the data raised by the study for any scientific or informative communication.
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 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	43.7 400
Water	26.9	26.8	26.75	26.72 467
Apricot jam	20	20	20	20 468
Pectin	0.8	0.8	0.8	$_{0.8}$ 469
Citric acid	0.14	0.24	0.29	0.32 470
Tricalcium citrate	0.08	0.08	0.08	0.08 471
Potassium sorbate	0.05	0.05	0.05	0.05 472
Apricot flavour	0.03	0.03	0.03	0.03 473

474 475 FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

47	6	Table 2. Nutritional com	position based on	Reg EU 1169/2011	of fruit fillings at different	sucrose content (g/100g).
• •	~	radie 2. reactional con	poblición oubea on	100, 10 1107/2011	or mane miningo de dimerente	saerose content (g) roog).

	FS	RS30	RS50	RS70 477
Energy (kJ)	964	831	724	620 478
Energy (kcal)	230	198	173	148 470
Fat	0	0	0	0 4/9
-of which saturated	0	0	0	0 480
Carbohydrates	57.0	41	30.5	20 481
-of which sugars	55.8	39	27.5	17 482
Fibre	1.0	15.0	22.5	30.0 483
Protein	0	0	0.6	0.9 484
Salt	0	0	0	0 485

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).

	Moisture content (MC) g H ₂ O/ 100 g of sample						
			t0	t30	t60	t180	
F		FS	20.50 ±0.02 bB	22.50 ±0.01 bA	23.50 ±0.01 bA*	22.83 ±0.01 bA	
	5 °C	RS30	22.67 ±0.01 aB	23.83 ±0.01 abA	24.17 ±0.01abA*	23.83 ±0.01 abA	
	50	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	
		FS	20.50 ±0.02 bB	22.00 ±0.01 bA	22.83 ±0.01 bA*	22.33 ±0.01 bA	
25° C	RS30	22.67 ±0.01 aB	23.33 ±0.01 aAB	23.67 ±0.01 bA*	23.83 ±0.01 aA		
	25 C	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	v)		
			t0	t30	t60	t 180	
		FS	0.800 ±0.010 dA	0.801 ±0.014 dA	0.805 ±0.007 dA	0.794 ±0.004 dA	
	5 °C	RS30	0.836 ±0.007 cAB	0.836 ±0.009 cAB	0.842 ±0.004 cA	0.832 ±0.003 cB	
	50	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	
		FS	0.800 ±0.010 dA	0.798 ±0.009 dA	0.804 ±0.010 dA	0.784 ±0.004 dB	
	25° C	RS30	0.836 ±0.007 cA	0.833 ±0.009 cA	0.839 ±0.003 cA	0.824 ±0.006 cB	
	25 C	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	
All the data a	are expres	sed as me	ean ± standard deviation	ons; different letters c	lose to number indica	te significative difference among	
sample ($p \leq 0$	0.05), wh	ere the sm	all letters due to the s	ugar content, capital	letter due to the time of	of storage and * due to temperature	
of storage. F	S: full sug	gar; RS30	: 30% sugar reduction	i; RS50: 50% sugar re	duction; RS70: 70%	sugar reduction.	

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

	tO			t30			t60				t180				
				5°C		25°C		5°C		25°C		5°C		25°C	
			ΔE		ΔE		ΔE		ΔE		ΔE		ΔE		ΔE
FS															
	L^*	$35.42\pm1.70\;aA$		$33.16 \pm 1.27 aB$		$33.71 \pm 1.89 aB$		$30.71 \pm 1.35 aC$		$30.58 \pm 1.39 aC$		$30.51 \pm 1.16 aC$		$28.48 \pm 1.01 abD$	
	a^*	$10.71 \pm 1.28 aA$	-	$8.44 \pm 1.28 aB$	-	$9.19 \pm 1.91 aB$	-	$6.53 \pm 1.24 aC$	-	$5.70 \pm 1.53 aC$	-	$6.36 \pm 1.14 aC^{\ast}$	-	$4.87\pm0.92aC^{\ast}$	-
	b^*	$15.00\pm2.40aA$		$11.80 \pm 1.83 aB$		$13.35\pm2.72aB$		$8.50 \pm 1.39 aC$		$8.03 \pm 1.85 aC$		$8.27 \pm 1.56 aC$		$5.42\pm0.99aD$	
	ΔE	-		4.5		2.8		9.1		9.8		9.4		13.2	
RS30															
	L^*	$32.40 \pm 1.50 bA$		$30.98 \pm 0.42 bB$		$30.86 \pm 0.75 bB$		$29.57 \pm 0.78 bC$		$29.43 \pm 1.10 bC$		$29.52 \pm 1.24 bC$		$27.89 \pm 1.05 abD$	
	a^*	$9.18 \pm 1.78 bA$	5.3	$7.66 \pm 0.80 bB$	3.9	$8.51 \pm 1.59 bA$	5.2	$5.25 \pm 1.32 bC$	2.18	$5.16 \pm 1.94 abB$	2.4	$6.88 \pm 1.25 aD^\ast$	1.25	$4.10\pm1.05aB^{\ast}$	1.6
	b^*	$10.85\pm2.02 bA$		$8.71\pm0.76bB$		$9.03 \pm 1.34 bB$		$7.16 \pm 0.95 bC$		$6.03 \pm 1.50 bC$		$7.70 \pm 1.47 aC$		$4.10\pm0.79 bD$	
	ΔE	-		3.0		2.5		6.1		6.9		4.8		9.6	
RS50															
	L^*	$31.76 \pm 1.01 bA$		$29.70\pm0.54cB$		$29.71 \pm 0.52 cB$		28.97 ± 0.4 cC*		$28.28\pm0.37cC*$		$28.28 \pm 0.85 \text{cD}$		$27.74 \pm 1.14 bC$	
	a^*	$8.56 \pm 1.36 bA$	6.8	$6.07\pm0.90cB*$	6.3	$6.76\pm0.71cB*$	7.8	$4.10\pm0.62cC$	4.0	$4.35 \pm 1.15 bcC$	3.8	$4.78\pm0.95bC*$	3.77	$4.15\pm1.59aC^*$	1.7
	b^*	$9.65 \pm 1.26 bA$		$7.12\pm0.91cB$		$7.10\pm0.58cB$		$5.82\pm0.64cC*$		$5.34\pm0.48cC*$		$5.66 \pm 1.04 bC$		$4.11 \pm 1.01 \text{bD}$	
	ΔE	-		4.1		3.7		6.5		7.0		6.5		8.1	
RS70															
	L^*	$30.75 \pm 1.12 \text{cA}$		$30.26 \pm 1.0 cA \ast$		$29.53\pm0.4cB*$		$28.52\pm0.3cB*$		$28.17\pm0.40cC*$		$28.42\pm0.92cB$		$28.90 \pm 2.2 aBC$	
	a^*	$6.91 \pm 1.00 cA$	9.2	$5.51\pm0.90cB$	6.1	$5.92\pm0.57cB$	8.5	$3.74 \pm 1.12 cC$	4.7	$3.45\pm0.39cC$	4.8	$4.13\pm0.75bC\ast$	4.38	$2.50\pm0.88bD\ast$	3.4
	b^*	$8.00\pm0.69 cA$		$7.25 \pm 1.26 cB$		$6.68\pm0.53cB$		$5.42\pm0.73cC^{\ast}$		$4.60\pm0.41 \text{cC}$		$5.13 \pm 0.78 bC$		$3.06\pm0.81 cD$	
	ΔE	-		1.7		2.0		4.7		5.5		4.6		6.9	

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

All the data are expressed as mean \pm 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 ΔE associated to the reformulation while horizontally ΔE associated to the storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Bake stability (%)										
		tO	t30	t60	t180					
	FS	$77.75\pm0.10\ bA$	$69.75 \pm 0.12 \text{ aB}$	$69.13 \pm 0.05 \text{ aB}$	$62.38 \pm 0.09 \text{ aC}$					
5 °C	RS30	$81.58\pm0.05\;aA$	$75.54 \pm 0.13 \text{ aB}$	$68.63 \pm 0.07 \text{ aC}$	$60.71 \pm 0.09 \text{ aD}$					
5 C	RS50	$81.13\pm0.05\ aA$	$74.04 \pm 0.10 \text{ aB}$	$71.29 \pm 0.10 \text{ aB*}$	$58.46 \pm 0.08 \text{ aC}$					
	RS70	$85.04 \pm 0.05 \text{ aA}$	$76.04 \pm 0.10 \text{ aB}$	$69.67 \pm 0.09 \text{ aC}$	$60.21 \pm 0.07 \text{ aD}$					
	FS	$77.75 \pm 0.10 \text{ bA}$	74.67 ± 0.11 aA	$69.08 \pm 0.08 \text{ aB}$	$65.33 \pm 0.10 \text{ aB}$					
25° C	RS30	$81.58\pm0.05\;abA$	$76.71 \pm 0.07 \text{ aB}$	$69.13 \pm 0.08 \text{ aC}$	$63.46 \pm 0.09 \text{ aD}$					
25° C	RS50	$81.13\pm0.05~aA$	$76.25 \pm 0.04 \text{ aB}$	$65.29\pm0.05~aB$	$56.54 \pm 0.08 \text{ aB}$					
	RS70	$85.04 \pm 0.05 aA$	$72.04 \pm 0.08 aB$	$65.17 \pm 0.08 aC$	$62.13 \pm 0.09 aC$					

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

504 505 506 All the data are expressed as mean \pm 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 storage time and * due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.



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

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



519Figure 3. Sensory scores for consistency, taste, colour and overall acceptability of fruit filling at variable sucrose content.520Different letters close to the bar indicate significative difference among sample ($p \le 0.05$) where the small letters due to the sugar521content, capital letter due to storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70%522sugar reduction.







1	A fibre syrup for the sugar reduction in fruit filling for bakery application
2	
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28 Abstract

Clean label ingredients able to reduce sugar in food are highly demanded by the food industry. A new fibre syrup based on corn (Zea mays) 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 firmness, 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.

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

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).

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

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

In the frame of high sugar foods, bakery products which contain fruit-based filling are a growing sale sector (Cropotova et al., 2016). Fruit filling are mainly based on sugar, water, fruit puree/jam, flavour, and thickening agent (Wei et al., 2001). Despite the high sugar content of this food preparation, very 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).

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

In this work, same commercial fibre syrup was tested as buking agent ingredient to develop reducedsugar fruit filling formulations. Fruit fillings with different reduced-sugar levels were developed and characterised for their physicochemical and sensory properties at 5°C and 25°C for a storage period 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

A fibre syrup (MELTEC[®]) was obtained from HI-FOOD S.p.A. (Parma, Italy). It is a clean label 92 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 CIE Lab system, L* [0 (black) and 100 (white)], a^* ($-a^*=$ greenness and $+a^*=$ redness) and b^* ($-b^*=$ 102 103 blueness and $+b^*=$ yellowness) parameters were measured. At least, three measurements were taken 104 for each analysis.

Other ingredients used in the fruit filling recipes were: low-methoxyl (LM) pectin Classic AB 902
(Herbstreith&Fox KG, Werder, Germany), glucose syrup 60 dextrose equivalent DE "Glucoplus
361" (Uniglad Ingredienti, Cuneo, Italy), tricalcium citrate (Giusto Faravelli, Milano, Italy),
potassium sorbate (Giusto Faravelli, Milano, Italy), crystalline sucrose (British sugar, Peterborough,
UK), apricot jam (Rogelfrut, Cuneo, Italy), citric acid (Brenntag, Milano, Italy), apricot flavour
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 25°C or 5°C for analysis after 30, 60 and 180 days (t30, t60, t180). Filling formulations were 130

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

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

141 **2.3.2** °Brix and pH

[°]Brix of filling was measured using a refractometer HB 95 (Lega Italy, Ravenna, Italy) while pH with
a potentiometer pH7+ DHS Food (XS Instruments, Modena, Italy). At least three measurements were
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.

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

151 2.3.4 Textural and rheological properties

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

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

164

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

165 where σ is the shear stress (Pa), γ is the shear rate (s⁻¹), K is the consistency coefficient (Pa*sⁿ) and *n* 166 the non-Newtonian index (dimensionless).

167 Three measurements were performed for each batch for a total of six determinations for each168 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; ΔE 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_0) 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_1) was measured and grade of syneresis was calculated as percentage (%) = (F_1/F_0)*100. Three 181 replicates for each batch for a total of six determinations for each formulation were carried out. Bake stability was evaluated following Young and colleagues with slight modifications (Young et al., 2003). Fruit filling samples of 10 g were placed into a circular mould (\emptyset 35 mm) on a 7x7 cm layer of short crust. On the circular sample obtained, 4 points have been marked on the external part to measure the pre- and post-baking (200° C, 10 min, 903.008.05, IKEA, Leida, Netherlands) diameter. Bake stability percentage (B.S.%) has been calculated according with:

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

188 where $\mathcal{O}pb$ is diameter post baking while $\mathcal{O}bb$ 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

Data were processed with a three-way ANOVA using three fixed factors: recipe (R), storage time (St) and storage temperature (ST). The evaluation of single factor and their interactions in the variability of each parameter was obtained with the partition of total variance of sum square (SS%). Significant differences ($p \le 0.05$) among different samples were assessed by one-way-analysis of 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**

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

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

226

227 **3.1 Nutritional label information**

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

Energy decreased remarkably with the increase of the fibre syrup moving from 964 KJ/230 Kcal of
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**

Product stability at rheological, chemical and microbiological level is strongly related to water activity (a_w) and moisture content (MC). Both parameters for all samples during storage are reported 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 ≈0.80 in FS to ≈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 those developed by sugar. Indeed, sugar is highly hygroscopic and has higher capacity than fibre to 255 256 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 et al., 2015; Zahn et al., 2013). However, the increase of both parameters does not affect product microbiological stability because the product is acidic (pH ~3.6) and it is stabilised with a hot filling process. The use of fiber syrup as sugar substitute in non-acidic products should envisage acid regulation to ensure microbiological safety. MC was affected also by St which slightly fluctuated during storage probably due to a macroscopic water redistribution in the product. The storage temperature did not affect neither the moisture content and the water activity with only a slightly 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.

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

fitting allowed to calculate the non-Newtonian index (*n*, data not showed) and the consistency 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 K when used to reduce sugar above 30%. On the contrary, polydextrose (E1200) was found to 293 294 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 at both storage temperatures in all samples (more pronounced in FS). A decrease of L^* , a^* and b^* 300 301 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 ΔE 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.

Other fruit filling' quality features are the stability – preservation of the dimension at high temperature during baking (Agudelo et al., 2014; Young et al., 2003) and the absence of water syneresis as a migration of water from the fruit filling to the dough may lead to product inhomogeneity and stickiness (Cropotova et al., 2016). All filling formulations produced did not show water syneresis during storage. The absence of water syneresis also in the RSs in which MC and a_w were higher than in FS indicates that the fibre syrup had a positive technological role acting as stabilising ingredient.

Bake stability results (Table 6) indicated its addiction by St showing a decrease during storage in all
samples. Moreover, only at t0, formulations containing the fibre syrup showed a significantly increase
of their bake stability index if compared with FS highlighting an improvement of this quality indicator
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 scores were attributed to RS70, in particular for consistency which was evaluated with a score < 5327 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 ≈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

"melty", "sweet" and "fruity" were also found in the IDEAL filling in the study of (Agudelo et al., 336 337 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

4. Conclusions

"Sugar reduced" and "high in fibre" claims could be used to label reformulated fruit fillings by means of the use of a syrup based on chickpea and maize fibre as sugar replacer. The use of the syrup increased the a_w , MC as well as firmness, adhesiveness, K consistency coefficient and bake stability, while decreased the colour coordinates L^* , a^* , b^* . Storage time mainly affected the colour and the bake stability of all fruit fillings while the storage temperature presented a little or negligible effect on all studied parameters. When sugar was reduced by 30% the overall physicochemical and sensory properties of the reformulated fruit filling were found to be similar to the full-sugar counterpart.

The use of the fibre syrup as clean label ingredient was found to be a valuable ingredient on a technological standpoint, allowing to improve the nutritional profile of the product and to partially replace the bulking agent role of sugar.

360

361 Acknowledgments

362	The Authors would like to thank Francesca Petrelli for carrying out part of the experimental work.
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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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	43.7 400
Water	26.9	26.8	26.75	26.72 407
Apricot jam	20	20	20	20 468
Pectin	0.8	0.8	0.8	0.8 469
Citric acid	0.14	0.24	0.29	0.32 470
Tricalcium citrate	0.08	0.08	0.08	0.08 471
Potassium sorbate	0.05	0.05	0.05	0.05 472
Apricot flavour	0.03	0.03	0.03	0.03 473

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

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

	FS	RS30	RS50	RS70 477
Energy (kJ)	964	831	724	620 478
Energy (kcal)	230	198	173	148 179
Fat	0	0	0	0 470
-of which saturated	0	0	0	$0 \frac{400}{401}$
Carbohydrates	57.0	41	30.5	20 481
-of which sugars	55.8	39	27.5	17 482
Fibre	1.0	15.0	22.5	30.0 483
Protein	0	0	0.6	0.9 484
Salt	0	0	0	0 485

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

- 488 489 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 $H_2O/100$ g of sample									
		t0	t30	t60	t180					
	FS	20.50 ±0.02 bB	22.50 ±0.01 bA	23.50 ±0.01 bA*	22.83 ±0.01 bA					
5 °C	RS30	22.67 ±0.01 aB	23.83 ±0.01 abA	24.17 ±0.01abA*	23.83 ±0.01 abA					
5 C	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					
	FS	20.50 ±0.02 bB	22.00 ±0.01 bA	22.83 ±0.01 bA*	22.33 ±0.01 bA					
25° C	RS30	22.67 ±0.01 aB	23.33 ±0.01 aAB	23.67 ±0.01 bA*	23.83 ±0.01 aA					
25 C	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)						
		tO	t30	t60	t 180					
	FS	0.800 ±0.010 dA	0.801 ±0.014 dA	0.805 ±0.007 dA	0.794 ±0.004 dA					
5 %	RS30	0.836 ±0.007 cAB	0.836 ±0.009 cAB	0.842 ±0.004 cA	0.832 ±0.003 cB					
50	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					
	FS	0.800 ±0.010 dA	0.798 ±0.009 dA	0.804 ±0.010 dA	0.784 ±0.004 dB					
25° C	RS30	0.836 ±0.007 cA	0.833 ±0.009 cA	0.839 ±0.003 cA	0.824 ±0.006 cB					
25 C	RS50	0.861 ±0.005 bA	$0.857 \pm 0.004 \text{ bA}$	$0.858 \pm 0.010 \text{ bA}$	0.846 ±0.010 bB					
	RS70	0.874 ±0.003 aA	0.871 ±0.004 aA	$0.875 \pm 0.003 \text{ aA}$	0.865 ±0.002 aB					

491 492 493 494 All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among

sample ($p \le 0.05$), 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.

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

500

	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)

		tO			t3	0			t6	0			t1	80	
				5°C		25°C		5°C		25°C		5°C		25°C	
			ΔE		ΔE		ΔE		ΔE		ΔE		ΔE		ΔE
FS															
	L^*	$35.42\pm1.70~aA$		$33.16 \pm 1.27 aB$		$33.71 \pm 1.89 aB$		$30.71 \pm 1.35 \mathrm{aC}$		$30.58 \pm 1.39 \text{aC}$		$30.51 \pm 1.16 \mathrm{aC}$		$28.48 \pm 1.01 abD$	
	a^*	$10.71 \pm 1.28 aA$	-	$8.44 \pm 1.28 aB$	-	$9.19 \pm 1.91 aB$	-	$6.53 \pm 1.24 aC$	-	$5.70 \pm 1.53 aC$	-	$6.36 \pm 1.14 aC^*$	-	$4.87\pm0.92aC^{\ast}$	-
	b^*	$15.00\pm2.40aA$		$11.80 \pm 1.83 aB$		$13.35\pm2.72aB$		$8.50 \pm 1.39 aC$		$8.03 \pm 1.85 aC$		$8.27 \pm 1.56 aC$		$5.42\pm0.99aD$	
	ΔE	-		4.5		2.8		9.1		9.8		9.4		13.2	
RS30															
	L^*	$32.40 \pm 1.50 bA$		$30.98 \pm 0.42 bB$		$30.86 \pm 0.75 bB$		$29.57\pm0.78bC$		$29.43 \pm 1.10 bC$		$29.52 \pm 1.24 bC$		$27.89 \pm 1.05 abD$	
	a^*	$9.18 \pm 1.78 bA$	5.3	$7.66 \pm 0.80 bB$	3.9	$8.51 \pm 1.59 bA$	5.2	$5.25 \pm 1.32 bC$	2.18	$5.16 \pm 1.94 abB$	2.4	$6.88 \pm 1.25 \mathrm{aD}{*}$	1.25	$4.10\pm1.05aB\ast$	1.6
	b^*	$10.85\pm2.02 bA$		$8.71 \pm 0.76 bB$		$9.03 \pm 1.34 bB$		$7.16 \pm 0.95 bC$		$6.03 \pm 1.50 bC$		$7.70 \pm 1.47 \mathrm{aC}$		$4.10\pm0.79bD$	
	ΔE	_		3.0		2.5		6.1		6.9		4.8		9.6	
RS50															
	L^*	31.76 ± 1.01 bA		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	
	<i>a</i> *	$8.56 \pm 1.36 bA$	6.8	6.07 ± 0.90 cB*	6.3	6.76 ± 0.71 cB*	7.8	4.10 ± 0.62 cC	4.0	$4.35 \pm 1.15 bcC$	3.8	$4.78 \pm 0.95 bC^*$	3.77	$4.15 \pm 1.59aC^*$	1.7
	b^*	$9.65 \pm 1.26 bA$		$7.12\pm0.91\text{cB}$		$7.10\pm0.58cB$		$5.82 \pm 0.64 cC^{*}$		5.34 ± 0.48 cC*		$5.66 \pm 1.04 bC$		$4.11 \pm 1.01 \text{bD}$	
	ΔE	-		4.1		3.7		6.5		7.0		6.5		8.1	
RS70															
	L^*	$30.75 \pm 1.12 \text{cA}$		$30.26 \pm 1.0 cA^{\ast}$		$29.53\pm0.4cB*$		$28.52\pm0.3cB*$		$28.17\pm0.40cC\ast$		$28.42\pm0.92cB$		$28.90 \pm 2.2 aBC$	
	<i>a</i> *	$6.91 \pm 1.00 cA$	9.2	$5.51\pm0.90cB$	6.1	$5.92\pm0.57 cB$	8.5	$3.74 \pm 1.12 \text{cC}$	4.7	$3.45 \pm 0.39 \text{cC}$	4.8	$4.13\pm0.75bC*$	4.38	$2.50\pm0.88 bD\ast$	3.4
	b^*	$8.00 \pm 0.69 cA$		$7.25 \pm 1.26 cB$		$6.68\pm0.53cB$		$5.42\pm0.73\text{cC}^{\ast}$		$4.60 \pm 0.41 \text{cC}$		$5.13 \pm 0.78 bC$		$3.06\pm0.81 \text{cD}$	
	ΔE	-		1.7		2.0		4.7		5.5		4.6		6.9	

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

All the data are expressed as mean \pm 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 ΔE associated to the reformulation while horizontally ΔE associated to the storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

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

Bake stability (%)										
		tO	t30	t60	t180					
	FS	$77.75 \pm 0.10 \text{ bA}$	$69.75 \pm 0.12 \text{ aB}$	$69.13 \pm 0.05 \text{ aB}$	$62.38 \pm 0.09 \text{ aC}$					
5 °C	RS30	$81.58 \pm 0.05 \text{ aA}$	$75.54 \pm 0.13 \text{ aB}$	$68.63 \pm 0.07 \text{ aC}$	$60.71 \pm 0.09 \text{ aD}$					
5.0	RS50	$81.13 \pm 0.05 \text{ aA}$	$74.04\pm0.10~aB$	$71.29 \pm 0.10 \text{ aB*}$	$58.46 \pm 0.08 \text{ aC}$					
	RS70	$85.04 \pm 0.05 \text{ aA}$	$76.04\pm0.10~aB$	$69.67 \pm 0.09 \text{ aC}$	$60.21 \pm 0.07 \text{ aD}$					
	FS	$77.75 \pm 0.10 \text{ bA}$	$74.67 \pm 0.11 \text{ aA}$	$69.08 \pm 0.08 \text{ aB}$	$65.33 \pm 0.10 \text{ aB}$					
250 0	RS30	$81.58 \pm 0.05 \text{ abA}$	$76.71 \pm 0.07 \text{ aB}$	$69.13 \pm 0.08 \text{ aC}$	$63.46 \pm 0.09 \text{ aD}$					
25° C	RS50	$81.13 \pm 0.05 \text{ aA}$	$76.25 \pm 0.04 \text{ aB}$	$65.29 \pm 0.05 \text{ aB}$	$56.54\pm0.08~aB$					
	RS70	$85.04 \pm 0.05 \text{ aA}$	$72.04 \pm 0.08 \text{ aB}$	$65.17 \pm 0.08 \text{ aC}$	$62.13 \pm 0.09 \text{ aC}$					

All the data are expressed as mean ± standard deviations; different letters close to number indicate significative difference among sample

504 505 506 $(p \le 0.05)$, where the small letters due to the sugar content, capital letter due to storage time and * due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

Figure 1. Firmness and adhesiveness of fruit fillings at variable sucrose content during storage at different temperatures (black:

507 508 509 510 5° C, grey: 25°C). Different letters close to the bar indicated significative difference among sample (p ≤ 0.05) where the small

letters were due to the sugar content while capital letter to storage time, and * symbol represented the difference due to storage temperature. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.

> 5 4 aAaA Firmness (N) 3 bAb/ aC_aB bΑ bA 2 cAc/ CACB bB 1 0534 ED PS-10 B-10 B-10 1000 430 t30 0 Person Person to at - Con 460 49 49 t180 ş 3 5 3 aC -30 aAB aCaB Adhesiveness (N/s) bC bBbB bB -20 bB bE bE h/ bcBbc h/ -10 0 PC.So 1000 Post Cost 40 AN and an Post Post to as And Con Post -To Stop en an PCSş ş ş ç t0 t180 t30 t60

Figure 2. Consistency index of fruit fillings at variable sucrose content during storage at different temperatures (black: 5°C, grey:

513 514 515 516 25°C). Different letters close to the bar indicate significative difference among sample ($P \le 0.05$) where the small letters due to the sugar content, capital letter due to storage time and * symbol due to storage temperature. FS: full sugar; RS30: 30% sugar

reduction; RS50: 50% sugar reduction; RS70: 70% sugar reduction.



Figure 3. Sensory scores for consistency, taste, colour and overall acceptability of fruit filling at variable sucrose content.

519 520 521 Different letters close to the bar indicate significative difference among sample ($p \le 0.05$) where the small letters due to the sugar content, capital letter due to storage time. FS: full sugar; RS30: 30% sugar reduction; RS50: 50% sugar reduction; RS70: 70% 522 sugar reduction.



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





Implications for gastronomy

Nowadays, one of the major trends in food science and gastronomy in the food reformulating area is the improvement of the nutritional value by the reduction of sugar. Due to the crucial role of sugar in food quality, its reduction is challenging. This problem is amplified by another trend that is the consumer demand for clean ingredients and labels which ask for not E numbers - sugar substitutes. The fibre syrup studied in this work can be used in different gastronomy applications such as fruit filling, jam, jellies and similar to replace the bulking agent functionality of sugar particularly where there is a clean label need and/or when "Sugar reduced" and "high in fibre" claims are pursued. In addition, the facility of using the fibre syrup as substitute (partially) of glucose syrup, sucrose and glucose makes interest and easy its use in pastry shops or in catering facilities to produce reduced in sugar and high in fiber fruit filling which can be used in products as croissant, doughnuts, cakes."

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

Supplementary Material

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